WHOLE BUILDING COMMISSIONING

BY

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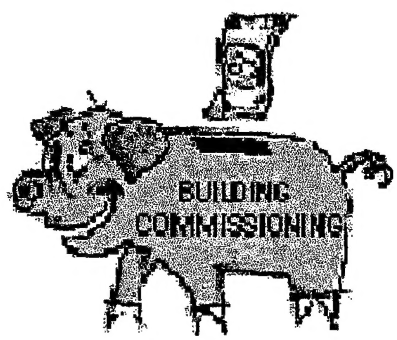

Whole Building Commissioning **Ensures Quality**
While Saving Time and Money

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ABSTRACT

The primary goal of this paper is to familiarize the reader with the building commissioning concept. Building commissioning gets its name from the process in which the Navy commissions ships and submarines by ensuring the vessel performs properly as intended before they are put out to sea. It is also similar to processes used in the Pacific Northwest and Canada as well as in the construction of factories and industrial facilities. Designing, specifying, and ensuring performance are the keys to realizing the benefits of building commissioning.

Building commissioning is a relatively new process just coming into focus in the 1990's. The first National Conference on Building Commissioning was held in Sacramento in 1993. It developed out of a 1992 Commissioning Roundtable meeting, sponsored by the Bonneville Power Administration, among Pacific Northwest and California utility representatives, federal and state government personnel, and energy professionals. Participants at the Roundtable agreed that the industry needed to establish a regular, national forum for the discussion of building commissioning.

The driving force behind the insurgence of building commissioning has been the lack of "quality" from decades of low-bid, lowest-cost, corner cutting. This current philosophy of shortsighted practices continues to produce mediocre, minimum code buildings that really ended up costing more to build and even more to operate. "Total" or "Whole" building commissioning is a proven process to replace these unreliable construction practices of yesterday by basically insisting on quality assurance.

This is not to say that commissioning will solve all the building problems. No building is ever "perfect," however each project that utilizes the commissioning process gains in quality and performance. There are three myths that must be overcome:

- commissioning can fix a bad design;
- commissioning can solve problems with unscrupulous contractors; and
- if construction documents are precisely followed, systems will work well.

There are numerous success stories from around the US, Canada, Europe, and Japan of people who have employed the quality assurance techniques involved in commissioning the total building. They give strong testimony that building commissioning is a small up-front investment that substantially pays off over the life cycle.

Building Commissioning is a strong tool for owners/agencies to achieve a “high performance” building. One that reduces energy consumption (which not only saves money, but also helps our environment), provides more comfort (better indoor air quality), and saves on the operation/maintenance costs.

What will the future hold for building commissioning? Is it a new fad or will it prove the test of time? I believe it is here to stay, but there may be many hybrids of its original scope developed over the years to better meet the specific needs of owners/agencies. Only by continuing the education of owners/agencies on the benefits to them and society as a whole, will the practice of building commissioning increase.

CHAPTER 1

Executive Summary

1.1 A Commissioning Fable

Once upon a time there was a man who needed to get from here to there. So he bought a plane ticket to his destination. On the day of his departure, he arrived at the gate to discover that the plane was late.

When the plane finally rolled up to the gate and the flight attendant began taking tickets, the man was informed that he would have to pay an additional 10% to cover the unexpected cost of moving the plane from the hangar to the gate. The passenger was frustrated, but he had already invested a lot in his plane ticket, so he handed over the additional 10%.

At last he and all the other passengers boarded. As the plane taxied down the runway, the pilot announced: "This airplane is a new, one-of-a-kind model. We're honored that you could join us for the first test flight ever of this aircraft."

Only a few of the passengers heard this announcement. Most were too preoccupied with attempting to adjust their seatbelts, which were jammed. Passengers on the right-hand side of the plane began to complain that their fans only blew hot air. Passengers on the left side realized that their fans only blew cold air. Flight attendants tried to improve the situation by offering soft drinks to the passengers on the hot side and coffee to the passengers on the cold side. However, their beverage cart was too wide to fit down the cabin aisle. Passengers began to feel faint and nauseated from the poor air quality in the cabin.

Meanwhile in the cockpit, the captain, who had received no training with the more advanced, efficient technologies on this aircraft, was having trouble figuring out how to make the plane take off. He tried consulting the manual, but it was written for a different system (and appeared to be missing pages, anyway).

Taken at face value, this story seems absurd. What passenger in his or her right mind would fly on such an aircraft? And what airline would purchase such a poorly performing

aircraft in the first place? However, people are willing to accept and occupy buildings under these circumstances on a regular basis.

No wonder so many occupants and owners of commercial buildings are dissatisfied. The equipment in their buildings fails to operate as intended. Operators do not receive adequate training and documentation. Occupants are less productive due to indoor air quality and comfort problems.

There is a remedy: building commissioning (total or partial). Building commissioning is the systematic process (beginning in the design phase, lasting at least one year after project close-out, and including the training of operating staff) of ensuring, through documented verification, that all building systems perform interactively according to the documented design intent and the owner's operational needs. [1]

The above excerpt is presented here as an excellent (and humorous) analogy of what can be expected from a building that is not properly commissioned. While one would expect aircraft to be fully tested prior to production and public use, buildings regularly are not, which, with no exaggeration, results in the same problems as the hapless aircraft in this story. When we are describing the reality of our industry, it really is not very humorous. Buildings are complex and one-of-a-kind (even identical designs have significant differences due to the different trades, products and people involved). Buildings need commissioning.

Owners are increasingly recognizing building commissioning as an effective means of reducing costs and ensuring quality as well as performance in building systems. Building owners are demanding higher performance in their buildings from their engineers, architects, and contractors. Smart owners and discerning engineers recognize that price and quality are two sides of the same coin in a building process. The plan-spec-bid-build process typical in most public, institutional, and private sector projects is seriously flawed. The growth of the building commissioning movement is a long over due effort to infuse quality into this flawed process.

The conventional plan-spec-bid process diffuses responsibility, muddies the performance measures, and does not allow for an integrated process for the delivery of the final product a functioning, high performing building. The three main players the owner, the design team, and the contractor team are engaged in a triangular relationship that is contractually and inherently unstable. This relationship is also confrontational by its nature, blame shifting by its practice, and actually rewards poor performance (Table 1.1.).

Table 1.1 Conflicting expectations in building process

Owner's expectations	A/E expectations	Contractor expectations
A/E delivers design that meets owner's use requirement.	Masterpiece gets built without changes.	Build project and move on to next project.
A/E delivers design that's maintainable.	Paid for basic services in a timely manner.	Plans and specs are clear, concise, and error-free.
A/E supervises the construction.	Additional compensation for non-basic services.	Build what is on the plans and specs without being responsible for building performance or evaluating design.
A/E will tell owner of construction defects.	Does not want to supervise construction.	Want the owner and A/E to be responsible and expect the impossible.
Contractor to build/work in a workmanlike manner in accordance with general accepted construction practices.	Does not want to deal with change orders.	Paid in a timely fashion.
Contractor to build work with good quality material free from defects.	Does not want to deal with owner/contractor disagreements.	No delays or provide compensation for delays.
Contractor to build work for agreed-to price.	Doesn't want to address RFI's from job site.	Time and money allowed for extras.
Contractor to build work on schedule.		
Contractor to pay his subcontractors and suppliers in a timely fashion without liens.		

Source: Carl N. Lawson, Richard Tyler, Esq.

Unfortunately, this conventional process is widely used by government, institutional, and many private sector owners. The traditional process promotes finger pointing, generates expensive change orders, and leads to high litigation costs. This model systematically sacrifices quality in the name of the lowest price. This in turn discourages creativity and

innovation in the name of risk management. It also stifles teamwork among the principal players in the name of schedule control. Other factors making commissioning of buildings necessary are shown in Table 1.1.2.

Table 1.1.2 Traditional factors supporting the need for a building commissioning program.

- Unclear design intent
- Complex building systems
- Unclear standards and criteria for gauging system
- Lack of functional performance testing
- Conflicts between drawings/specifications and applicable codes
- Inadequate system documentation
- Maintainability and equipment accessibility problems
- Inadequate provision for maintenance
- Inadequate O&M manuals
- Inadequate training of O&M staff
- Numerous change orders and cost overruns

Source: GSA Building Commissioning Guide, 1997

1.2 Construction Industry Reality

The building industry is currently enjoying a robust rebound after years of downturns. While the design consultants are once more busy designing new buildings or renovating old ones, the costs to owners continue to climb as building systems get ever more complex and regulatory requirements ever more stringent. In the 1990s, the technologies used in buildings have made significant advances, particularly in the computer based technologies.

The reality to building owners is the fact that there is a pervasive absence of quality in the finished product. To a vast majority of owners, buildings are not performing as expected.

An astonishing number of their projects are woefully under performing. Substantial completion on many projects is merely the start of a lengthy shakedown period for a myriad of building system problems that often can take a year or longer to sort out the bugs and defects.

Owners who think they have already paid for and are getting quality are engaging in self-denial. Exercises in cost cutting, value engineering, and down scoping invariably affect the quality of a project. In far too many projects, cutting out quality has been the business norm, not the exception. Sadly, only a tiny minority of buildings are designed and constructed with such attributes as quality, innovation, and teamwork that are exhibited by other sectors in our economy that excel in high performance (Table 1.2.).

Table 1.2 Top 10 deficiencies discovered by commissioning new and existing buildings.

- Incorrect scheduling of HVAC and lighting equipment.
- Incorrect cooling and heating sequences of operation.
- Incorrect calibration of sensors and instrumentation.
- Lack of control strategies for optimum comfort and efficient operation.
- Malfunctioning air and water-side economizers.
- Under-utilized computer-based control systems.
- Short cycling of HVAC equipment leading to premature failure.
- Lack of design intent and building documentation.
- Lack of training for building operators or service contractors on complex systems.
- Missing specified and paid-for equipment.

Source: Portland Energy Conservation, Inc.

1.3 Dissatisfaction with Building Performance

For a vast majority of building owners and facility managers, the functional performance of their building systems are simply not meeting their expectations. A study of 60 commercial buildings for which the results were presented at the1994 National Conference on Building Commissioning, sponsored by Portland Energy Conservation, Inc., found that:

- More than half of the buildings suffered from control problems.
- 40 percent have HVAC equipment problems.
- 25 percent had energy management control systems (EMCS), economizers, and/or variable speed drives (VSDs) that did not run properly.

1.4 Owner Demand and Expectation

The building owners and operators are no longer content with poorly designed and non-performing buildings. Marginal performance directly translates to the bottom line costs for building owners. In the era of downsizing and budget cuts, they can no longer afford or ignore costly fixes. If design engineers continue to fail in meeting owners' expectations, they will become irrelevant in the market place.

1.5 Litigation

Building defects and malfunctioning HVAC systems have led to numerous lawsuits by building owners. In fact, litigation and liability concerns often influence design decisions and construction methods. Litigation never improves a building's performance or its quality; it merely drains the pockets of all parties involved (except the lawyers, of course).

1.6 Owner Peace of Mind

As the plane story highlights, total building commissioning for the owner helps ensures that:

- the project is on time
- the project is within the budget
- the design is proper to meet owners needs
- the systems and sub-systems perform properly
- the operators are properly trained
- the documentation is correct and sufficient

1.7 Commissioning Benefits

It seems everyone involved in the construction process is in a big hurry while holding tightly to his or her wallets. The principal players have lost their sense of purpose in their respective efforts, which is to deliver to their customer, the owner, a productive, healthy work environment that enhances value to their employees or tenants.

Inspection is not enough to ensure quality in buildings. Control measures must be integrated and interwoven throughout the entire delivery process from the project program through design, construction, and turnover. A high performance car cannot be manufactured if we simply engage in rejecting an unacceptable product. The carmaker must develop a quality control process that makes a smooth running car an achievable reality. Building commissioning is the quality control tool for building owners to the same end.

The benefits of a thorough and rigorous commissioning process are self-evident and not just only for the owners (Table 1.7).

Table 1.7 Benefits of Commissioning for Owners

- Reduce change orders and claims.
- Reduce project delays.
- Enforce start-up requirements.
- Shorten building turnover period.
- Reduce post-occupancy corrective work.
- Minimize effects of design defects.
- Improve productivity and indoor environment.
- Increase maintainability and reliability.
- Reduce energy and operating costs.
- Increase value by better quality construction.

Contractors and subcontractors know that on those jobs with commissioning requirements, it is not advisable for them to cut corners. Contractors and their subcontractors also benefit from their ability to lower their cash set-asides for warranty reserves and call-backs. The architects can expect a building with far smaller post-construction headaches for them to handle. The engineers know the HVAC systems are virtually assured of working as intended, thus eliminating post-occupancy troubleshooting visits. The owners know that the promised savings from fewer costly change orders and lower operating and maintenance costs will occur. The design team gains the prospect of repeat and expanded business from a satisfied owner. The time wasted and cost incurred in litigation or claims can be channeled to more productive endeavors.

Building commissioning, when properly and rigorously implemented, makes everyone a winner. The biggest winner, however, is the customer—the building occupants. For them, there are two very noticeable benefits:

1. Increased productivity
2. A paradigm shift back to quality

1.8 Increased Productivity

Owners, design engineers, and architects must first redefine what a building is to them. Is a building and its systems simply to be a utility closet, a Taj Mahal, or a showcase of engineering marvel? Commissioning pioneers, such as Dr. Charles Dorgan of HVAC&R Center in Wisconsin, have been pressing owners to realize that buildings are "productivity engines." A poorly performing building and its systems directly impact the "bottom line" and the "mission" for which the building was built in the first place. By redefining buildings as "productivity engines" in which value is added, net profit is generated, and unnecessary costs avoided, owners will come to view quality in a very different light. A higher performing building with a smooth functioning HVAC system produces a higher level of productivity by its occupants. This fact is especially important in today's concern over indoor air quality.

A healthy building with quality HVAC and lighting systems conveys caring by a company to its employees. It garners greater loyalty, reduces distraction and complaints, reduces time lost due to environmental irritants, and enhances creativity. When an owners and designer are willing to cut corners, they will eventually compromise the purpose of the building.

1.9 A Paradigm Shift Back to Quality

For too long, owners, designers, and contractors have devised a process in which the schedule and cost are the end games. In fact, on most projects, these two out-comes are the only basis for monetary incentives. Building commissioning introduces a fundamental paradigm shift from the price/schedule dimension to a quality-focused dimension.

To building owners, the bottom line cost savings can be dramatic. Savings in energy costs can be between 20 to 50 percent. Maintenance and operational savings can be between 15 to 35 percent. Cost and savings are compared in more detail later in the report. [2]

1.10 Building Commissioning's Future

Since building commissioning is still in its infancy, many building owners are still unaware of the benefits commissioning can bring to their facilities. The move is to educate owners by:

- Working through associations such as Building Owners and Managers Association (BOMA) and International Facility Management Association (IFMA)
- Educating architects/engineers and also encouraging them to educate building owners
- Provide owners with case studies and testimonials to demonstrate the value of commissioning
- Continuing to offer the National Conference, as well as regional seminars and workshops, on building commissioning

Future success requires a continued effort to integrate the diversity of stakeholders involved in the building construction and operations industry.

I submit that building commissioning is not just an interim-"fix" rather commissioning is a necessary ingredient for successful buildings in the foreseeable future.

CHAPTER 2

Commissioning Overview

Building owners spend more on complex building systems than ever before, yet many find they are not getting the performance they expect. A recent study of 60 commercial buildings found that more than half suffered from control problems. In addition, 40 percent had problems with heating, ventilation and air-conditioning (HVAC) equipment and one-third had sensors that were not operating properly. An astonishing 15 percent of the buildings studied actually were missing specified equipment. And approximately one-quarter of them had energy management control systems, economizers and/or variable speed drives that did not run properly. A building is an investment. Poor performance means you may be losing money. Excessive repair and replacement costs, employee absenteeism, indoor air quality problems and liability and tenant turnover cost U.S. building owners and employers millions of dollars each year.

Building commissioning is one way to keep this money in your pocket. Building commissioning can restore an existing building to high productivity. It can ensure that a new building begins its life cycle at optimal productivity and improves the likelihood that the building will maintain this level of performance.

2.1 Building Commissioning Defined

Commissioning is a systematic process—**beginning in the design phase, lasting at least one year after project closeout and including the training of operating staff**—of ensuring, **through documented verification**, that all building systems perform

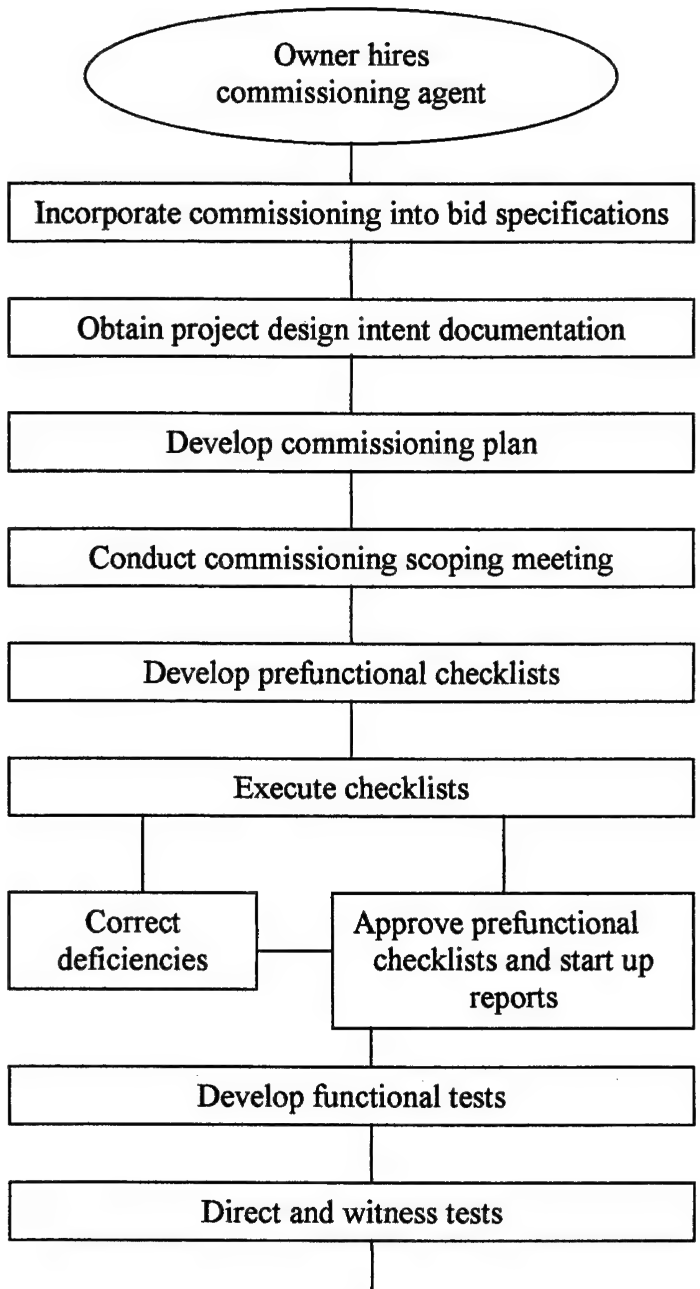
interactively according to the documented design intent and the owner's operational needs.

Commissioning occasionally is confused with testing, adjusting and balancing (TAB). Testing, adjusting and balancing measures building air and water flows, but commissioning encompasses a much broader scope of work. Commissioning involves functional testing to determine how well mechanical and electrical systems work together. Functional tests of equipment and systems also help determine whether the equipment meets operational goals or whether it needs to be adjusted to increase efficiency and effectiveness. Commissioning results in fewer callbacks, long-term tenant satisfaction, lower energy bills, avoided equipment replacement costs and an improved profit margin for building owners.

Figure 2.1

The Commissioning Process

The typical commissioning process involves the following steps.



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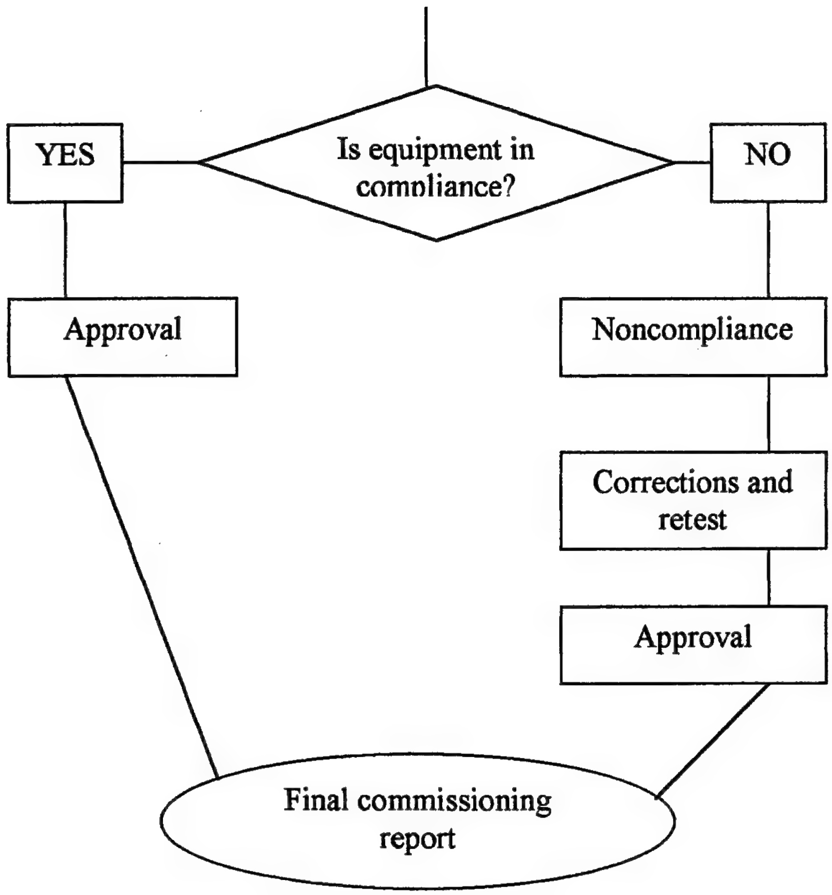
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NO
Approval
Noncompliance
Corrections and retest
Approval
Final commissioning report

CHAPTER 3

Benefits of Building Commissioning

The traditional method of building design and turnover does not come close to ensuring a building will meet the performance needs of the owner and building occupants. In addition, the needs of facility maintenance personnel are not addressed, preventing them from maintaining the building's performance at maximum efficiency.

Until recently, the most frequently mentioned benefit of commissioning was its energy-related value. Building commissioning ensures the energy savings and improved performance expected from facility upgrades. While this benefit is significant, it is far outweighed by the non-energy-related benefits of commissioning. These include:

- Fewer system deficiencies at building turnover
- Improved indoor air quality, occupant comfort and productivity
- Decreased potential for liability related to indoor air quality
- Reduced operation and maintenance and equipment replacement costs

Below are several other benefits from building commissioning.

During Construction

- Identifies and meets owner requirements in accordance with the design intent
- Helps meet cost objectives by reducing costly change orders due to errors and omissions
- Reduces contractor callbacks, allowing contractor to focus efforts on other projects and obtain payments on schedule
- Reduces construction time due to fewer conflicts and change orders

During Occupancy

- Verifies the facility meets or exceeds minimum energy efficiency standards
- Ensures facility operated in accordance with original design intent
- Contributes to a comfortable, safe, and healthy environment by improving power quality, and indoor air quality
- Helps provide adequately trained staff to operate and maintain the building according to the design intent
- Reduces energy and operating costs by operating and maintaining systems at maximum efficiency
- Reduces occupant complaints, minimizing costly service calls; and
- Provides documentation and training for operators and facility managers, ensuring continued savings and longer equipment life

3.1 Fewer System Deficiencies at Turnover

All too often, building owners accept buildings at turnover whose systems may "work" but do not work optimally or as intended. During the rush to complete essential building elements prior to occupancy, owners frequently are forced to temporarily overlook incomplete or deficient systems. Many owners have neither the time nor the resources to deal with the burden of remedying deficiencies perceived as "less important." Some system deficiencies are never even noticed during close-out, because inspections and punchlists focus primarily on items that are critical to obtaining regulatory occupancy permits and opening the building.

Once the building is turned over to the owner, the over-looked deficiencies must be addressed. Getting contractors to return to the job after substantial completion and

occupancy can be difficult, with the result that, again, "less important" deficiencies are never fully addressed. Deficiencies that were not identified before occupancy may come to the attention of facility staff by tenant complaints or through routine operations. Often facility staff spends their own time correcting items that still fall under the responsibility of the contractor. Other deficiencies may be significant enough that the facility staff attempt the difficult process of asking the contractor to return and make the corrections. Still other deficiencies go permanently undetected, to the detriment of building control, energy use, equipment reliability, and tenant comfort.

The primary goal of commissioning is to prevent or mitigate all of these problems. The commissioning agent's task is to identify system deficiencies as early in the project as possible and to track their status until they are corrected. By identifying deficiencies early and by using a systematic process for making corrections, the commissioning agent assists the construction team in providing building systems, prior to occupancy, with significantly fewer defects.

3.2 Improved Indoor Air Quality (IAQ), Comfort and Productivity

Surveys indicate that comfort problems are common in many U.S. commercial buildings. A recent Occupational Safety and Health Administration report noted that 20 to 30 percent of commercial buildings suffer from indoor air quality problems. Building occupants complain of symptoms ranging from headaches and fatigue to severe allergic reactions. In the most severe cases, occupants have developed Legionnaire's disease, a potentially fatal bacterial illness. The National Institute of Occupational Safety and

Health surveyed 350 buildings with deficient indoor air quality and found that more than half of the complaints stemmed from HVAC systems that were not maintained properly. Although little research has been completed to document the link between comfort and productivity, common sense tells us that comfortable employees are more productive than uncomfortable employees. The few studies that have been conducted on this topic agree. Below is an estimate of productivity losses in a typical office building where occupants complained of discomfort. [3]

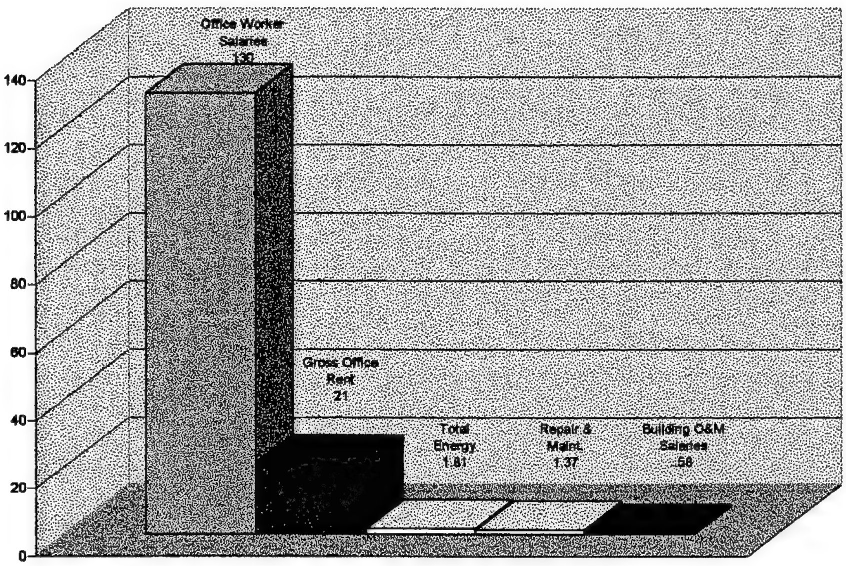
Table 3.2 Comfort and Productivity

Payroll costs	$150/ft$_2$ /year
Productivity lost to complaint time	$.10/ft$_2$ /year

This example assumes that this typical building has one occupant per 200 ft 2 of space and an annual payroll cost of $30,000/person or $150/ft 2 of office space. If one out of every five employees spends only 30 minutes a month complaining about the lighting or the temperature or both, the employer loses $.10/ft 2 in annual productivity. For a 100,000 ft 2 building, this amounts to $10,000 per year. Because uncomfortable employees probably spend more than just half an hour each month complaining about building comfort, the actual losses likely would be higher.

If comfort problems are severe enough to make employees ill, business owners sustain additional productivity losses to cover sick time. Building operation costs also increase, as operators respond to more tenant complaints. Figure 3.2. shows a typical allocation of operating costs in a 140,000 ft 2 office building.

Figure 3.2 Operating costs for a 140,000 ft_2 office building (1990 \$/rentable ft_2)



Source: E-Source calculation from BOMA and EPRI data.

Commissioning also improves the productivity of processes, especially in industrial facilities. By ensuring that equipment performs optimally and efficiently, commissioning can help reduce equipment downtime and improve production rates. These problems do not only concern building owners who occupy their buildings. They affect owners who rent building space as well. How long will tenants who are experiencing discomfort and low productivity remain tenants? Tenant turnover can be costly, according to the following estimated cost of losing a tenant in Class A office space. [4]

Table 3.2.1 Cost of Losing a Tenant

Five-year lease value	$262,500
Rent loss due to vacancy	$26,250
Improvements for new tenant	$52,500–$70,000
Leasing commission	$13,125
Total cost of losing tenant	$91,875–$109,375

Assuming an average office size of 3,500 ft 2, rented at $15/ft 2 a year, a typical five-year lease has a value of $262,500. If a tenant leaves, this space will remain vacant an average of six months, for a total rent loss of $26,250. Improvements and build-outs to satisfy a new tenant usually run $15 to $20/ft 2, or $52,500 to $70,000 in this case. On top of all this, the building owner often pays a leasing commission of 5 percent of the five-year lease value, or $13,125. Thus, the total cost of losing one tenant could run from $91,875 to $109,375, or 35 to 42 percent of the five-year lease value. If a building develops a reputation for being uncomfortable and unproductive, the vacancy period could last longer. Word of uncomfortable building conditions is likely to spread among business peers; market research shows that dissatisfied customers, in this case tenants, are likely to complain to 7 to 10 of their peers.

Building commissioning is one tool building owners can use to avoid the expenses and productivity losses associated with poor indoor air quality and employee discomfort. Because commissioning assures that HVAC and other building systems are installed and operating properly, proper commissioning can prevent these problems. In existing buildings, commissioning detects current and potential indoor air quality/comfort problems and helps identify solutions.

3.3 Liability Related to Indoor Air Quality

Sick building syndrome and the court cases associated with it continue to make headlines across the country. The government of Polk County, Florida recently won nearly $26 million in damages for problems with its "sick" courthouse. Although the general contractor paid this award, many building owners also are feeling the sting of indoor air

quality lawsuits brought by occupants who complain of illnesses resulting from building air quality. And even when owners are on the receiving end of litigation settlements, they and their tenants still suffer the inconvenience of acquiring other work space for use during the repair process, not to mention the inconvenience of the litigation process itself, which can drag on for months and even years.

Building commissioning protects owners in more than one way. First, it provides documented verification of a building's performance and operation. Owners should request that the commissioning process include testing of outside-air flow rates, a primary factor affecting indoor air quality. If an existing building has deficiencies, the commissioning agent also records the repairs made. Commissioning should be repeated throughout the life of a building, and performance documentation should be updated regularly. This documentation provides owners with a record of building performance that can be used as evidence in the event of a lawsuit. Commissioning also helps prevent many indoor air quality problems through its focus on training building operators in the proper maintenance of building systems. Properly run and maintained HVAC systems, with clean coils and air intakes and regularly changed filters, are less likely to contribute to indoor air quality problems. In addition, trained operators can spot potential air quality and ventilation problems before they develop.

3.4 Reduced Operation/Maintenance/Equipment Replacement Costs

Operation and maintenance and equipment replacement costs always will take up a portion of building budgets. However, more building owners and businesses are realizing that operation and maintenance departments can minimize life cycle costs by changing

operation and maintenance practices. That is, proper operation and maintenance actually can save money compared to poor operation and maintenance, and many businesses are reinvesting their operation and maintenance savings in more efficient building systems. The commissioning process establishes sound operation and maintenance building practices and trains operators in carrying out these practices.

Commissioning also allows building owners to avoid premature equipment replacement costs. Commissioning verifies that equipment is installed and operating properly. Equipment that operates as intended lasts longer, works more reliably, and needs fewer repairs during its lifetime. By promoting equipment reliability, commissioning reduces service, energy and maintenance costs. Equipment that operates properly uses less energy, requires fewer service calls and demands less "crisis maintenance" from onsite staff (or expensive outside contractors), allowing them to concentrate on their normal duties.

3.5 Results

The bottom line is that commissioning improves a building's asset value. Properly functioning buildings with reliable equipment kept in good condition are worth more than their uncommissioned counterparts. Commissioned systems and equipment retain their value longer. There is a higher demand for comfortable, healthy working space that promotes productivity. Systems that function properly use less energy, experience less downtime and require less maintenance, which save building owners money.

CHAPTER 4

Economics of Building Commissioning

4.1 Costs

There currently is no standard method of reporting the costs and savings associated with commissioning. For many projects, commissioning costs were never separated from other project costs. For projects where these costs have been tracked separately, various methods have been used to report them. Table 4.1 lists some of the most common methods. No matter which estimation method is used, however, commissioning accounts for a very small portion of overall construction and renovation budgets.

Table 4.1 Estimated Commissioning Costs

Commissioning Scope		Estimated Cost Range
Whole building (controls, electrical, mechanical) Commissioning from design through acceptance		0.5–1.5% of total construction cost
HVAC and automated controls system only		1.5–2.5% of mechanical contract
Electrical system only		1–1.5% of electrical contract
Various energy-efficiency measures		
	53,000 ft 2 avg.	\$.08–\$.64* ft 2 /yr
	102,000 ft 2 avg.	\$.13–\$.43** ft 2 /yr

**$.23 avg. cost for 16 buildings*
***$.28 avg. cost for 7 buildings*

Commissioning costs can vary considerably from project to project. Actual costs depend on the size and complexity of the project, and the extent and rigor of the commissioning specified.

4.2 Savings

Methods for reporting the savings associated with commissioning vary depending on who is receiving the report. Utilities typically have been interested in determining the kilowatt-hour savings associated with commissioning energy-efficient systems and equipment. Building owners, however, usually are more interested in learning how much commissioning will save them in annual utility bills and operation and maintenance costs. Just as commissioning costs can vary from project to project, so do commissioning savings. Savings depend on the scope of the commissioning. Table 4.2 shows reported savings for certain types of buildings.

Table 4.2 The Savings from Commissioning

Building Type	$ Savings	Energy Savings
110,000 ft 2 office	$.11/ft 2 /yr ($12,276/yr)	279,000 kWh/yr
22,000 ft 2 office	$.35/ft 2 /yr ($7,630/yr)	130,800 kWh/yr
60,000 ft 2 high-tech	$.20/ft 2 /yr ($12,000/yr)	336,000 kWh/yr

When commissioning is done properly, the savings can be substantial.

CHAPTER 5

Commissioning Case Studies

5.1 Capital Circle Office Complex in Tallahassee

Canadian engineer Wayne Dunn was called on by the State of Florida to commission the prototype buildings the state had begun building in its new Capital Circle Office Complex in Tallahassee. Seven buildings later the state is building the most energy efficient buildings it's ever had in less time for lower costs, and getting more useable floor space and higher occupant satisfaction. More significantly, the practice of building commissioning has become the centerpiece of a quality control effort that is spreading its savings throughout the public sector of Florida.

The commissioning worked so well that with each new building the state cloned, quality continued to rise while costs and construction time continued to fall. On the last building there were over 50 different improvements they made from results learned on the previous buildings.

They went from 77% space efficiency utilization for office buildings to 87%. A 10% increase, which in this case is like gaining $5.7 million in free office space. The time went from a median 1,158 days project development time to 680 days, which resulted in more than a year saved. Faster occupancy of the building and greater return on investment. Lower maintenance costs were also realized. They gained built-in access to technology that is adaptable to future developments and high-performance energy

efficiency. The total energy costs are 90 cents a square foot per year. That is less than half of the comparable cost for this state.

They set a two-watt per square foot figure as a target and they bettered that mark. Other state buildings energy costs run from a high of up to 13.6 watts per square foot, down to a low of 4.8. The average was about 5.6. They now have the capability of getting into new buildings at 1/3 of the best energy operating costs. Building commissioning has enabled them to retrofit existing state buildings with energy cost cuts of 20%. [5]

5.2 Jacksonville Community College

Jacksonville Community College was in need of a new facility. They low bid at $21.5 (million). The college only had $19.2 for the total project budget. However, they had already low bid. They called Florida Department of Management Services (DMS) who has been a driving force for building commission in Florida and asked for help. DMS put together a building commissioning team and began analyzing the project. They did not cut quality, in fact they improved quality and found alternative ways of producing the same result. The job was built at $19.2 with the same amount of space. Had they awarded it at $21.5, and had the contractor gone in with the typical way of (one) bid-shopping and (two) substitution of materials, every savings that the contractor would have made, (the same savings that DMS made for the college), would have gone to the contractor. [6]

If building commission would have been started from the design phase on this project, even more savings could have been realized.

5.3 Walt Disney World

Walt Disney World started a major expansion in the late 1980s. As a result of that expansion, they had a number of successive building failures. Many of these failures occurred immediately after construction and, in some cases, delayed the initial opening of projects. The failures that they were experiencing were also occurring elsewhere with other owners of new buildings. In many cases, these failures were in facilities that had strong heating, ventilation, and air-conditioning (HVAC) drivers.

As a result of successive failures, they implemented a three-step building commissioning process in 1990, which has been largely applied to all of their new construction since that time. At the time they did not know that what they were doing was actually called building commissioning.

The result of implementing this process over the years has given Disney a lot of sound feedback from designers and contractors. Much of this feedback has challenged long-standing beliefs, such as the need to delay the installation of drywall and final finishes before the building spaces are thoroughly conditioned. This feedback has been important in the development of their building commissioning manual. This is what has allowed them to substantially improve building performance while simultaneously not impacting project cost and schedule.

Disney has completed approximately $750 million of construction using this process. It has been well tested: multiple designers, out-of-state designers, world-class designers, all

different types of construction. Since they have implemented building commissioning, they have had no high-consequence failures. They have had some standard, low-consequence failures. You cannot prevent every problem, but they have managed to avoid the multimillion dollar "Delay In Opening Day" kinds of failures.

In Vero Beach, Disney was building a vacation resort. The initial cost of this facility was $29 million. They implemented this building commissioning process. They value-engineered the cost down to $22 million: a $7 million decrease. That is more than 20 percent, and they did it with no decrease in square footage. It was all taken out in small amounts: $20,000 here, $50,000 there. The building commissioning cost $25,000 but saved over $300,000 by eliminating unnecessary items. Now that's a real over-achievement. The reason commissioning costs were so low is that hotels have repetitive facilities. They have the same air-conditioning system, the same wall system, and the same room size, repeated several hundred times. Disney found real opportunities for cost saving without compromising the performance of the building. [7]

5.4 Canadian Building Commissioning

The Head of Commissioning within Maintenance/Operational Assurance, Public Works and Government Services of Canada, Jean Paul Laramee is overseeing the commissioning of two new major projects with many buildings: a forensic lab (new building) for the world-famous Royal Canadian Mounted Police (RCMP) and a $45 million federal justice building. Other projects that his group will commission are "major retrofits," part of a 3-5 year, $500 million renewal of the nation's capital. This is part of a

general rebuilding and refitting program of the federal Parliament and Ministerial buildings in the national capital area, Canada's equivalent to the Capitol Hill area of Washington, D.C. [8]

5.5 Local Government Center, Salem

The Local Government Center, a new 40,000 ft 2 office building in Salem, was commissioned to resolve installation and operating problems and to promote energy efficient HVAC operation. To accomplish these goals, the commissioning agent focused on energy, operation and training issues. Some of the deficiencies identified during commissioning included: higher-than-average carbon dioxide levels in one room, air balance problems that affected thermal comfort, economizer wiring problems, intake of fireplace smoke from adjacent buildings and inaccurate as-built documents. The building's tenants have noticed several non-energy benefits from the commissioning process:

- Numerous construction-related system problems were discovered and corrected at contractor expense
- Outside air quantities, air temperatures and carbon dioxide levels were documented
- Operating staff received additional training
- The construction and design team may have been more diligent in carrying out their responsibilities because of the involvement of a third-party commissioning agent. [9]

5.6 Highrise Office Building, Portland

A 278,000 ft 2 , 18-year-old office building located in down-town Portland was commissioned to identify low-cost operation and maintenance improvement opportunities. The building's duct heaters, chiller system, energy management control system, lighting controls and air handlers were commissioned (that is, tuned up to optimize performance) in 1995. Because of the narrow scope of the tune-up, the costs and savings associated with it are low. The commissioning effort cost $12,700. This cost included the commissioning agent fee, the cost to pre/post-monitor equipment to document commissioning savings and the cost to repair deficiencies. The major deficiencies identified by commissioning included:

- Electric reheat scheduling and setpoint problems
- Chilled water setpoint was too low
- Space sensors were out of calibration
- The chiller was short-cycling due to improper time delay setting

Repairing these deficiencies has resulted in annual energy bill savings of $8,145. In addition, the operating staff has found that building temperature control and thermal comfort have improved. The O&M documentation available for troubleshooting also was improved by commissioning. [10]

5.7 Portland Government Office Building

At the initial commissioning meeting all indications were that this would be a well-run, deficiency-free project. The general contractor was one of the largest and most organized in the business and the project manager appeared to be running a very tight ship. All parties at this first meeting talked as though their only concern was to build a quality building. Communication paths were clear. The mechanical, controls and balancing contractors were working together. What could go wrong? The systems to be commissioned included an energy management and control system (EMCS), variable speed drives for the main supply and return fans, lighting sweep controls and daylighting controls. These are relatively complex systems and the commissioning scope was interpreted broadly to ensure that the customer would be happy with the end result. Commissioning the EMCS meant verifying all of the main HVAC controls sequences. Below are some of the problems the commissioning agent identified:

- Due to an incorrect EMCS setpoint, the perimeter fan-powered terminal unit reheat fans would not come on when heating was required. This had severe comfort as well as energy implications.
- Spot-checking the air balance report by the commissioning agent yielded a number of significant discrepancies. Several areas were starved for air.
- A thermostat for one zone was faulty. The contractor corrected this by exchanging it with a thermostat from a neighboring zone rather than by replacing it.
- One electric duct heater could not energize.
- A perimeter VAV box had failed electronic components and no access door.
- The lighting sweep control was in chaos. Override zones were frequently improperly assigned if they were assigned at all. Pushing an override button in one area often turned on lights in a zone a hundred feet away. Virtually every test on the sweep controls failed. This testing was further confounded by very poorly documented sweep circuitry. Eventually this was all corrected although at the cost of repeated

visits by the commissioning agent, much intervention by the engineer and much foot-dragging and stone-walling by the controls contractor.

- The daylighting controls were not properly calibrated, so the perimeter lights failed to dim. In addition, the unexpected installation of dark carpeting invalidated the lighting calculations and made stable control very difficult.
- Sprinkler piping penetrated the ductwork in two places, causing an obstruction and inadequate air flow to those areas.
- When first checked, the supply air temperature reset controls were not programmed. After programming, the sequence was causing occasional simultaneous heating and cooling.
- The rooftop unit shipping restraints were not removed.
- The EMCS trend logs were not programmed. [10]

CHAPTER 6

The Commissioning Process

This section outlines the commissioning process and the decisions a building owner must make in order to start the process. The earlier commissioning is incorporated into a new construction or renovation project, the better the cost-benefit ratio will be. It's easier—and cheaper—to make changes on paper during the design phase than on the site once the project is underway.

6.1 Roles and Responsibilities of Project Team

Members of a design-construction project team, like components of integrated building systems, need to interact in order to perform their tasks successfully. Commissioning actually facilitates this interaction, because it sets clear performance expectations and requires communication among all team members.

The whole construction project should begin with a commissioning scoping meeting, which all team members are required to attend. At this meeting, the roles of each team member are outlined and the commissioning process and schedule are described. The project team most often includes the building owner or developer, general contractor, commissioning agent, design professionals, contractors, subcontractors and manufacturer's representatives. The team also may include the facility manager and/or building operator, and possibly testing specialists and utility representatives. Ideally, each of these parties contributes to the commissioning process. Of course, few situations are

ideal. Budget considerations and special project characteristics may expand or minimize the commissioning roles and responsibilities described below.

Owners should consult with their commissioning agents about potentially combining some of the following roles. The commissioning agent can review the scope of commissioning and advise the owner on how best to consolidate roles and tasks.

6.2 Owner/Agency

The building owner's most significant responsibility is to clearly communicate expectations about the project outcome. Often the owner is represented by a construction manager or project manager, who is given authority over project budgets and goals. The owner's expectations are used by the designer to establish the design intent of the project and by the commissioning agent to evaluate whether this intent is met. Other responsibilities of the building owner or owner's representative include:

- Hiring the commissioning agent and other members of the project team, preferably using a competitive request for proposal process
- Determining the project's budget, schedule and operating requirements
- Working with the commissioning agent to determine commissioning goals
- Facilitating communication between the commissioning agent and other project team members
- Approving startup and functional test completion (or delegating this task to a construction or project manager)
- Attending building training sessions when appropriate

6.3 General Contractor

The general contractor assists with the development and implementation of functional performance testing for all systems. This involves assisting in gathering information (for existing buildings these may include shop drawings, operations and maintenance manuals and as-built documents) for review by the project team. The general contractor facilitates the commissioning schedule by coordinating activities with owner representatives and subcontractors. [11]

6.4 Commissioning Agent/Authority

One of the most important commissioning decisions a building owner or agency can make is selecting the commissioning authority. Owners can use a competitive request for proposal (RFP) process to make the selection.

Once a list of the commissioning agents that seem appropriate for your project has been developed, a statement of qualifications should be requested from each of them. A sample commissioning agent solicitation is included in Appendix B.

In the RFP, the owner must request details on previous, relevant commissioning experience, including the depth of commissioning experience. Recommended commissioning agent qualifications are discussed in more detail in the following pages.

The commissioning agent's primary tasks include:

- Ensuring the completion of adequate design intent documentation
- Providing input on design features that facilitate commissioning and future operation and maintenance
- Assisting in developing commissioning specifications for the bid documents
- Developing the commissioning plan
- Writing pre-functional and functional performance tests (refer to Appendix B for samples)
- Ensuring that team members understand their specified commissioning responsibilities and fulfill them on schedule
- Submitting regular reports to the building owner or project manager
- Directing all functional performance testing and approving contractor startup tests, air and water testing and balancing, and duct pressure testing (the commissioning agent also may perform some functional performance tests)
- Writing a final commissioning report documenting the final evaluation of the systems' capabilities to meet design intent and owner needs
- Reviewing and commenting on technical considerations from design through construction, to facilitate sound operation and maintenance of the building
- Reviewing contractor and manufacturer training plans prior to delivery to operators and facility managers
- Reviewing operation and maintenance manuals and design intent documentation for completeness

Owners have several parties to choose from when selecting a commissioning agent.

They include:

- Independent third party
- Design professional
- General contractor

• Mechanical contractor

Each option has its advantages and disadvantages. The final choice may depend on the complexity and the specific needs of the particular project.

6.4.1 Independent Third Party

Many owners who have commissioned their buildings recommend using an independent third party (that is, someone who is not otherwise a part of the design-construction team) as the commissioning agent. An independent commissioning agent, under contract to the owner (or to the owner's construction or project manager) rather than the general contractor, can play an objective role and ensure that the owner truly will get the building performance he or she expects. The commissioning agent could work with the owner's project manager. The independent third-party option offers owners the most objectivity, but also entails managing an additional contract, which may result in higher first costs than some of the other options. For large and/or complex projects, especially in buildings with highly integrated, sophisticated systems, future savings from commissioning outweigh these higher first costs.

Independent commissioning agents, who often are trained as design engineers or architects, should have the qualifications listed under "Commissioning Agent Qualifications," and they should be able to write commissioning specifications for bid documents. Hands-on experience with building systems is especially critical. It's important to involve the independent agent as early in the design phase as possible. This allows the agent the opportunity to document the design intent for the project, begin

scheduling commissioning activities and begin writing commissioning specifications into bid documents for other contractors. For existing buildings, the commissioning agent must try to determine from building documentation what the original design intent was, what the current use of the building requires of its systems and how it relates to any planned renovations or upgrades. The earlier this relationship is understood, the clearer the commissioning specifications can be.

6.4.2 Design Professional

For projects ranging from 20,000 to 100,000 ft 2, using the design professional as the commissioning agent is often a good option, provided that the project specifications detail the commissioning requirements. The advantage of using the design professional as the commissioning agent is that he or she already is familiar with the design intent of the project. This familiarity somewhat reduces first costs. Most design professionals have the ability to write specifications and oversee the commissioning process. However, they may not have adequate experience in day-to-day construction processes and trouble shooting systems. Owners considering this option should bear in mind that commissioning is not included in most design professional fees. Commissioning provisions must be written into the design professional's contract, so firms can include these services in their bids.

6.4.3 General Contractor

General contractors, provided they have experience with projects of similar size and complexity, have the scheduling and construction background necessary to supervise a

commissioning agent in the quality control manager sense. However, they typically need to hire a commissioning agent to directly super-vise tests performed by installing contractors. It has been argued that it is not in the owner's best interest to have the commissioning agent work for the general contractor because of the obvious conflict of interest. On the other hand, because they want to meet project deadlines, general contractors have more of an incentive to cooperate in scheduling and completing the commissioning work. Commissioning often reduces the number of callbacks on a project, and thus improves the general contractor's profit margin. If the commissioning agent will be under contract to the general contractor, it's recommended that the agent be hired as an independent contractor without affiliation to any firm on the design or construction team and that the agent report to the owner's representative (usually the construction or project manager).

6.4.4 Mechanical Contractor

It used to be standard practice for many mechanical contracting firms to conduct performance tests and systematic checkout procedures for equipment they installed. As construction budgets became tighter, this service was dropped from most projects. Mechanical contractors may have the knowledge and capability to test mechanical equipment. Using them as commissioning agents, however, has been referred to as "letting the fox guard the henhouse." Some contend that it's difficult for mechanical contractors to objectively test and assess their own work, especially since repairing deficiencies found through commissioning may increase their costs. But many owners

have good relationships with their contractors, and it may be appropriate to use them as commissioning agents in cases where:

- The project size is less than 20,000 ft 2
- One mechanical contractor performs all of the mechanical work on a project
- The project specifications clearly detail the commissioning requirements

6.4.5 Commissioning Agent Qualifications

Although some groups are looking into the possibility of developing commissioning agent certification, currently there is no standard certification or licensing process for commissioning agents. It is therefore up to each owner to determine the agent qualifications appropriate for a given project. On the next page are some guidelines for selecting a qualified commissioning agent.

Regardless whom you choose to act as the commissioning agent, there are certain minimum qualifications any commissioning agent should possess. Certain projects may require more or less experience, depending on size, complexity and other building characteristics. The commissioning agent chosen should be directed to subcontract work in which he or she lacks sufficient experience.

6.4.6 Commissioning Agent Qualifications Checklist

In general, for complex projects, a commissioning agent who personally will develop the commissioning test plans and directly supervise the commissioning work should meet these qualifications:

Recommended Minimum Qualifications

√ Experience in design, specification or installation of commercial building mechanical control systems. This experience also may be related to general HVAC systems.

√ Experience with at least four projects involving successful troubleshooting and/or performance verification of buildings of at least similar size as the current project. Experience with new and/or existing buildings, depending on the current project.

√ History of responsiveness

√ Meets owner's liability requirements

√ Experience working with project teams and conducting scoping meetings; good communication skills

√ Experience with at least two projects involving commissioning of HVAC, mechanical controls and lighting control systems in buildings of similar size to the current project. This experience includes the writing of functional performance test plans.

Optional Qualifications

√ Direct responsibility for project management of at least two commercial construction projects with mechanical costs greater than or equal to current project costs

√ Experience in design installation and/or troubleshooting of direct digital controls and energy management systems, if applicable

√ Demonstrated familiarity with testing instrumentation

√ Knowledge and familiarity with air/water testing and balancing

√ Experience in planning and delivering O&M training

6.5 Design Professionals

The primary commissioning responsibilities of design professionals are to document the design intent for all systems and controls and to make sure that commissioning is included in the bid specifications. The designer also should monitor construction activities and review and approve project documentation (shop drawings, operation and maintenance manuals, as-built drawings). For very complex projects, the commissioning agent may ask the designer to review commissioning plans and functional performance tests. The commissioning agent also may ask the designer to visit the site during construction or renovation (beyond the designer's typical construction observation responsibilities) to ensure that work is performed according to plans. If this is the case, the design professional's bid should include funds to cover these visits. As mentioned before, the design firm may be responsible for hiring and overseeing the commissioning agent.

6.6 Contractors/Subcontractors

Contractors and subcontractors are responsible for performing commissioning functions described in their bid specifications. These may include assisting with developing the commissioning schedule, conducting performance tests (under the supervision of the commissioning agent) of the systems they install, adjusting systems where appropriate and documenting system startup.

Contractors and subcontractors also are responsible for training building operators in the proper operation and maintenance of systems and providing operation and maintenance manuals on the equipment they install.

6.7 Manufacturers' Representatives

Manufacturers' representatives provide the commissioning agent with manufacturer specifications for the equipment installed. They also may assist contractors with operation and maintenance training and with functional performance testing, especially in situations where warranties may be affected by test results or procedures.

6.8 Facility Manager/Building Operator

The building operator should assist with (or at least be present for) as much of the functional testing as possible. This improves operator understanding of equipment and control strategies. The operator also should attend training sessions provided by manufacturers' representatives and contractors.

6.9 Testing Specialists

If special testing is needed due to the complexity of the project, the specialists performing these tests also should be involved in commissioning. Test results and recommendations from these specialists should be submitted to the commissioning agent for review. They also may be required to review documentation relating to the systems they test and to train operators on the proper use of this equipment.

6.10 Utility Representative

Some utilities offer services that can complement the commissioning process. It may prove to be very beneficial to call the local utility to find out what services they can provide. [12]

6.11 Phases of Building Commissioning

In general, any building commissioning process will fall into five phases. Depending on the project scope and size and whether it is major or minor construction, commissioning may not affect all phases.

- Program Phase
- Design Phase
- Construction Phase
- Acceptance Phase
- Post-Acceptance Phase

Table 6.11 shows how these phases correspond to construction and renovation project phase designations.

Table 6.11 Commissioning Phases and Tasks Corresponding to Project Phases

Commissioning Phase	Project Phase
Predesign ■ Commissioning agent hired	**Planning Phase** ■ Design team chosen
Design ■ Develop commissioning plan ■ Hold commissioning scoping meeting ■ Submit design intent documentation ■ Develop commissioning specifications ■ Review of design by commissioning agent	**Design Phase** ■ Building designed ■ Bid documents prepared ■ Job awarded to general contractor
Construction/Installation ■ Submitted documentation reviewed ■ Develop and execute prefunctional checklists ■ Develop functional test plans	**Construction Phase** ■ Construction of facility ■ Startup of equipment
Acceptance Acceptance ■ Execute functional tests ■ Verify operator training ■ Approve O&M manuals	**Phase** ■ Training completed ■ Documentation completed ■ Building accepted by owner
Post-acceptance/Occupancy ■ Perform deferred tests (if any)	**Occupancy Phase** ■ Ongoing O&M

6.12 Program (Pre-Design) Phase

The Program Phase lays the foundation for the other phases and defines the scope of the project based upon the agency's requirements and future expectations of the building. During the Program Phase, the operational, energy, and occupant requirements for the finished building are defined; construction budgets are planned; and a project management plan is developed. Particular emphasis is placed on documenting the function of the facility, identifying occupancy requirements, and developing a budget that incorporates life-cycle cost-effective energy efficiency components.

At this stage, the Construction Manager, Architect/Engineer (A/E) firm and the Commissioning Authority are hired. As part of the project management plan, the roles and responsibilities of key participates; owner, the Construction Manager, A/E firm, the Commissioning Authority, members of the design team, and contractors must be defined for the commissioning process. It is critical that the lines of communication are established at the very beginning, and that all team members understand the expectations of the project building, and the decisions that must be made to achieve this goal.

The most important documents generated during this phase are the project management plan prepared by the Construction Manager, initial statement of design intent prepared by the A/E firm, and a preliminary Commissioning Plan prepared by the Commissioning Authority. These documents form the guidance for building construction and form the basis by which the project will be judged as a success.

6.13 Design Phase

A recent survey of owners and professionals who had participated in commissioning projects found that all respondents felt commissioning should begin earlier in the design phase. The design team needs clear objectives for performing commissioning-focused quality assurance procedures on its design and for developing drawings and specifications that facilitate commissioning during the construction phase, including clear and complete commissioning specifications.

During the Design Phase, the design of the building (including all components and systems) is completed. The Commissioning Authority reviews the design to assure that it is in accordance with the design intent.

The design intent is a dynamic document that provides the explanation of the ideas, concepts, and criteria that are considered to be very important to the owner. It is initially the outcome of the programming and conceptual design phases. The design intent document should cover the following for each system, major component, facility, and area:

- Objectives and functional use of the system, equipment or facility.
- General quality of materials and construction.
- Occupancy requirements.
- Indoor environmental quality (IEQ) space temperature, relative humidity, indoor air quality (IAQ), noise level, etc.
- Performance criteria (energy efficiency, and tolerances of the IEQ objectives, etc.)
- Budget considerations and limitations.
- Restrictions and limitations of system or facility.
- Very general system description.

Specifications and contract documents are then prepared. In addition to these documents, the commissioning process requires that all changes to the initial design intent be documented, reviewed, and approved by the Commissioning Authority and owner.

The Commissioning Plan and commissioning specifications are also completed during the Design Phase. The Commissioning Plan details each Commissioning Team member's roles and responsibilities, procedures for verification of functional performance testing, project organization, staffing and commissioning schedule. The Commissioning Plan is used to develop commissioning specifications that become part of the contract documents.

The commissioning specifications detail the commissioning process and the scope of work for all participants including contractors and vendors. The specifications also identify the skills and qualifications required of all members of the Commissioning Team. They should include clear descriptions of the level of detail by which each component and system will be tested and document the performance standards.

6.14 Construction Phase

During the Construction Phase, the building shell is constructed; utility services are established; and all systems and components are installed, undergo testing, and begin operation. The commissioning agent reviews contractor submittals and operation and maintenance manuals and may write test plans for each system and piece of equipment to be commissioned. The agent also conducts field inspections regularly to assure the

construction complies with the design plans. The agent documents any conditions that might affect system performance or operation.

Pre-functional testing, which ensures that equipment is properly installed and ready for functional performance testing, occurs during the construction phase. The commissioning agent approves and may oversee startup and pre-functional testing and makes sure that any deficiencies are remedied before functional testing begins.

The commissioning agent should involve the building operation staff in the pre-functional and functional testing as much as possible. Doing so improves operator understanding of the proper operation of equipment and systems. It also provides operators with valuable hands-on training in running and troubleshooting the equipment they will manage.

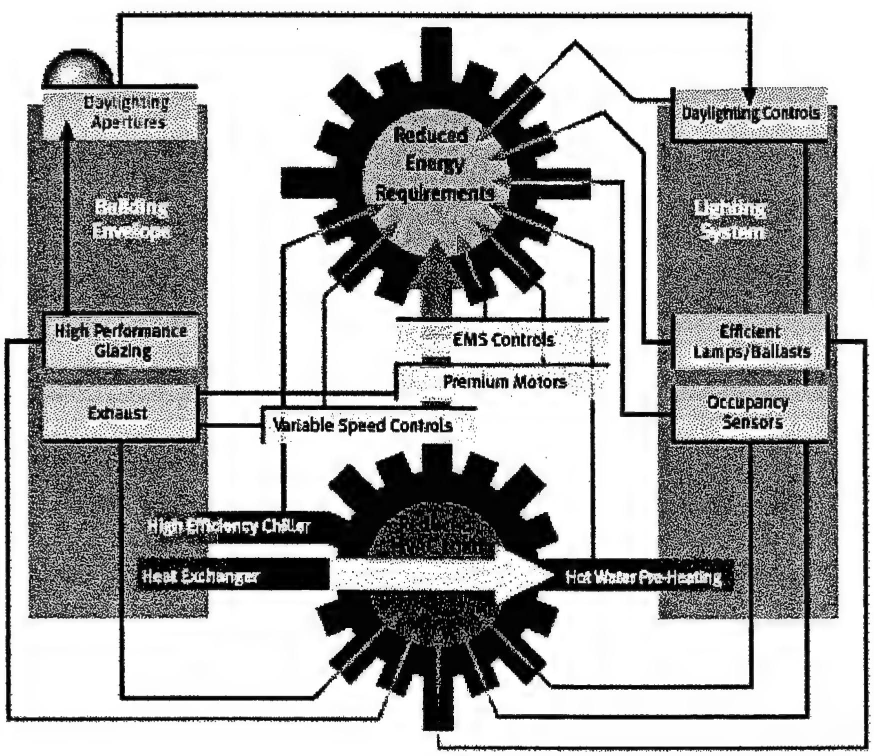
The commissioning agent may write various reports during construction that document testing progress as well as deficiencies that may affect future building performance. These reports may be submitted to the owner, design engineer, project manager or contractors, depending on the contract arrangements for the project. (Establishing a clear process for delivering correction orders to the responsible contractors and tracking their responses is critical to the success of commissioning). The Commissioning Plan is then modified to reflect all changes that are made to equipment and components during construction.

6.15 Acceptance Phase

The functional performance tests written during the construction phase are modified, if necessary, during the acceptance phase to reflect any changes in installations. Because total building performance is a function of the integrated performance of all components, functional performance testing ensures that equipment and systems are installed correctly, tested, and adjusted so that they operate at maximum efficiency according to the specifications both individually and cooperatively. Diagram 6.15. below illustrates the energy optimization that can be achieved when a building's systems are properly integrated.

Figure 6.15 Integrated System

Integrated systems may make a building more productive and comfortable for the occupants, and less costly to build and operate for the owner.



Most often, the commissioning agent directs the tests, but actual equipment operation during the tests is performed by subcontractors, particularly the controls contractor. If corrective measures are required, the commissioning agent makes sure that they meet the owner's criteria and the design intent. Acceptable performance is reached when equipment or systems meet specified design parameters under full-load and part-load conditions during all modes of operation, as outlined in the commissioning test plan.

After completing functional performance testing, the agent writes a final commissioning report, which includes all project documentation, and submits it to the owner for review.

The acceptance phase is complete when the facility has moved from the static construction state to the dynamic operating state free of deficiencies. Control of the building may have been transferred from the design/construction team to the owner and building operators prior to the completion of the acceptance phase. Part of this transfer involves training building operators in the operation and maintenance of equipment and systems. Preferably this training begins during the construction/installation phase, as discussed above. If training was not included in the construction/installation phase, it should begin before the end of the acceptance phase.

The commissioning agent is responsible for interviewing the project manager and operation and maintenance staff to determine their training needs. The agent then selects the appropriate topics, level of detail, sequence of training and training methods. Training may include both classroom sessions and hands-on site demonstrations of proper equipment operation and maintenance.

In addition, the commissioning agent oversees training sessions as specified in the bid documents that installing con-tractors, designers and manufacturers' representatives will conduct. The agent also verifies that operation and maintenance manuals are complete and available for use during the training sessions.

Finally, if any modifications to operation and maintenance practices are made based on the training, the agent makes sure that the manuals are updated to reflect these changes. All building staff responsible for operating and maintaining complex building equipment, especially energy management systems, should be required to participate in the training.

The commissioning agent may arrange for videotaping of the training and coordinate this videotaping with vendors. Video taping training sessions often provides an extra incentive for vendors to ensure the quality of the sessions.

6.16 Post-Acceptance Phase

After acceptance, the building is in the hands of the owner and operators. Even though the project is considered complete, some commissioning tasks continue throughout the life of the building. These tasks include ensuring that equipment and systems continue to function properly and documenting changes in equipment and building usage. It may be appropriate to continue working with the commissioning agent at the beginning of this phase, so the agent can review and recommend methods for carrying out these functions.

A post-occupancy review should occur after one to two years of occupancy to ensure that the building is operating as defined in the design document. This verification should be based on appropriate testing and operator and occupants interviews. The basis for assuring compliance with the design intent cannot be established by a simple building acceptance walk-through, but should be dependent on the equipment test results.

When performing testing during post-occupancy, the commissioning agent or test engineer must be careful not to void any equipment warranties. The building owner should require that contractors provide the commissioning agent with a full set of warranty conditions for each piece of equipment to be commissioned. Some warranty provisions may require that the installing contractor actually perform the testing, under the supervision of the commissioning agent.

If any testing was delayed because of site or equipment conditions or inclement weather, this testing should be completed during this phase. Any necessary seasonal testing also should be performed during post-acceptance. Although some testing of heating and cooling systems can be performed under simulated conditions during the off-season, natural conditions usually provide more reliable results. Simulation can be more expensive than testing under natural conditions. If the building already is occupied (especially if it's occupied 24 hours a day), simulation may be impossible. When performing seasonal testing during post-acceptance, the commissioning agent, as noted above, must be careful not to void existing warranty conditions.

Owners should consider re-commissioning their facilities periodically to ensure that performance levels continue to meet design intent. If building operators have been involved in the original commissioning effort, and if they received training that included the topics listed on page 30, they may be able to conduct the re-commissioning process themselves. [11]

CHAPTER 7

Levels of Commissioning

7.1 What Level is Required?

Because commissioning all building systems is rarely practical or even necessary, owners need to determine what level of commissioning is best and most cost-effective for their project.

Many factors affect this decision, including:

- The complexity of the building systems
- Building type and size
- Building usage
- Whether the project is new construction, or the renovation or tune-up of an existing building
- How much the owner is willing to spend
- Building tenant or occupant demographics

This section includes information about various factors owners should consider when determining the extent of their commissioning efforts. The level of commissioning detail usually is dictated by the complexity of the systems and controls installed. The more complex the project, the higher the risk of systems not performing as intended. Systems that are considered "complex" have:

- Sophisticated controls and control strategies
- Complicated sequences of operation
- A high degree of interaction with other systems and building equipment

For example, an upgrade from incandescent lighting to T8 fluorescent lamps with electronic ballast would not be considered a complex project, and probably would not need more than an inspection. On the other hand, if the lighting upgrade also included

lighting controls (such as sweep controls, occupancy sensors and daylighting controls), it would be considered complex and would benefit from commissioning. As a general rule, all projects that include controls, energy management control systems, pneumatic equipment, integrated systems, HVAC related plant equipment and air distribution systems should be commissioned.

But how much commissioning is enough? Unfortunately, the answer to this question is not straightforward. Certain types of equipment require less commissioning, under most conditions, than others. Because every building is different, and because building owners and occupants may have specific building performance needs, there are no hard and fast rules for determining the level of commissioning.

Two different levels of commissioning are described below, followed by a table listing various types of equipment and their recommended commissioning levels. Again, these are merely guidelines. Some owners may find that they really need Level 2 commissioning for a piece of equipment, when the table suggests Level 1 commissioning, and vice versa. In these cases, owners should consult with their commissioning agents to determine the most appropriate level of commissioning.

7.2 Commission Checklist

Experts commonly place the following energy conservation measures on their "must commission" lists:

- Lighting sweep or daylighting controls
- Energy management systems and control strategies
- Variable-speed drives

- Ventilation air control
- Building pressurization control
- Grocery refrigeration floating head pressure
- Grocery case anti-condensate heater controls

7.3 Level 1 Commissioning

Level 1 commissioning is a less formal process and requires the involvement of fewer players. Commissioning agents performing this less rigorous form of commissioning may find a "boilerplate" commissioning plan is sufficient, and thus less time and money are spent developing the commissioning plan.

During the design phase, the commissioning agent reviews design documents and ensures that commissioning is incorporated into the project specifications. For existing buildings, the commissioning agent may interview building operation staff about maintenance practices, building usage and their concerns.

7.3.1 Steps in Level 1 Commissioning

1. A site inspection of the installation, including verifying that the specified equipment was properly installed
2. Calibration checks for most sensors and thermostats and checks for proper setpoints
3. Simple functional performance tests, often using "boilerplate" forms
4. Verification of occupancy schedules to ensure proper settings
5. Verification that the owner and the persons required to operate the equipment have had proper training
6. Preparation of a final report detailing the commissioning findings

7.4 Level 2 Commissioning

Level 2 commissioning is a more rigorous process that involves more players. The commissioning agent performing this level of commissioning generally develops a customized commissioning plan and conducts a project scoping meeting to review the plan with other players. With complex projects, there are two approaches to Level 2 commissioning of HVAC and controls systems:

- Point-by-point verification
- Specialized testing to assure performance without the expense of point-by-point testing

Specialized testing may follow a proprietary approach that varies depending on the commissioning agent. When using specialized instead of point-by-point testing, the owner must rely on the commissioning agent to ensure that testing meets the desired rigor and thoroughness.

As with Level 1 commissioning, the commissioning agent reviews design documentation, interviews building operators and ensures that commissioning requirements are clearly spelled out in the project specifications.

7.4.1 Steps in Level 2 Commissioning

1. Commissioning agent review of design documentation that clearly describes design intent and includes such details as equipment specifications, sequence of operation, equipment submittals, setpoint schedules, occupancy schedules and manufacturers' performance data

2. Development and execution of pre-functional performance tests and checklists for each piece of equipment or system, or documentation of completed startup tests

3. Completion of rigorous functional performance tests (to test and verify such performance indicators as capacity, efficiency, sequence of operation, proper flows and how other equipment influences equipment performance)

4. Verification that O&M manuals are complete, available and accessible on site

5. Verification that operating staff have been trained to properly operate and maintain the equipment or system and that they have been instructed on how the equipment or system is integrated with the rest of the building's systems

6. Development or verification of a preventive maintenance plan or service contract (service contracts should have a preventive maintenance component that goes beyond merely responding to trouble calls and needed repairs)

7. Preparation of a final report detailing the commissioning findings

7.5 Finding the Right Balance

Level 1 commissioning is less expansive, and thus often less expensive, than Level 2 commissioning. However, it also provides less performance assurance. Owners and commissioning agents must find the proper balance between cost and performance assurance before beginning the commissioning process.

Owners and commissioning agents can ask the following questions to help determine the complexity of the system or equipment and therefore the need for commissioning. Place a checkmark in the box by each question where the answer is "Yes."

❑ Is the equipment relatively simple in operation and design?

❑ Does the equipment operate relatively independent of other equipment and systems?

❑ Is the investment in the equipment relatively small?

❑ Is the equipment expected to yield only small energy savings?

- ❑ Is the equipment free from adverse operating influences, such as a dirty environment, that affect proper operation?
- ❑ Does the equipment have a history of reliable performance?
- ❑ Is it difficult for occupants to circumvent or override equipment settings or operation?
- ❑ Is startup documentation available?
- ❑ Is test and balancing documentation available?
- ❑ Are detailed, written specifications available onsite?
- ❑ Are operation and maintenance manuals available onsite?
- ❑ Is the manufacturer closely involved with the project?

If an owner or commissioning agent can answer "Yes" to most of these questions, Level 1 commissioning probably is appropriate for the project.

If an owner can answer "No" to any of the first four questions, they should strongly consider Level 2 commissioning. Regardless of the answers to the first four questions, if even some of the remaining questions are answered with "No," Level 2 commissioning still should be strongly considered.

Table 7.5 provides general guidelines for selecting commissioning levels for representative equipment. These recommended levels should be evaluated based on the answers to the questions above. [12]

Table 7.5 Equipment Type and Suggested Level of Commissioning

Equipment Type	Equipment Name	Level 1	Level 2
Lighting	Lighting timer controls	■	
	Automatic daylighting controls		■
	Combination of related equipment		■
	Lighting sweep controls		■
HVAC System	Automatic night setback	■	
	Automatic economizer cooling		■
	Heat pump systems		■
	Outside air control	■	■
	Hot and cold deck reset		■
	Reheat system primary air optimization	■	■
	Heat recovery—HVAC systems	■	■
	Deadband thermostat	■	
	Time clocks on circulating pumps	■	
	Chiller system (chiller, pumps, controls)		■
	Separate make-up air for exhaust hoods	■	
	Variable air volume		■
	Variable speed drives		■
	Direct tower cooling (chiller strainer cycle)		■
	Multiple chiller control		■
	Radiant heating	■	
	Cooling tower flow control		■
	Evaporative cooling		■
	Direct expansion cooling system COP		■
	Building pressurization		■
	Combination of related equipment		■
Domestic Hot Water	Unoccupied period control of water heaters	■	
	Heat pump water heater		■
	Circulating pump control	■	
	Heat recovery—DHW systems	■	■
	Combination of related equipment		■
Power-Related	Motors	■	
	Motor controls		■
	Combination of related equipment		■
Refrigeration	Optimize defrost controls		■
	Refrigeration pressure optimization		■
	Case anti-condensate heaters	■	■
	High-efficiency compressors		■
	Combination of related equipment		■
Miscellaneous	Energy management control system		■
	Combination of related equipment		■

CHAPTER 8
Commissioning Close Out

Commissioning ensures that a building is performing as intended at the time that commissioning occurs. This means that to maintain this level of performance, commissioning, in a sense, never ends. Certainly no one could reasonably expect building operation staff to perform functional tests on equipment and systems daily. However, operation and management staff should be encouraged to recommission selected building systems on a regular basis, perhaps every two to three years depending on building usage, equipment complexity and operating experience.

The commissioning agent can recommend an appropriate interval for your building and systems. In the meantime, staff should implement sound operation and maintenance practices to ensure that the savings from commissioning last.

8.1 Operation and Maintenance

To ensure that the benefits gained from commissioning persist over time, sound operation and maintenance practices must be in place. Some of these practices include:

- Establishing and implementing a preventive maintenance program for all building equipment and systems
- Reviewing monthly utility bills for unexpected changes in building energy use
- Using energy accounting software to track building energy use
- Tracking all maintenance, scheduled or unscheduled, for each piece of equipment; reviewing these documents periodically often will indicate whether certain pieces of equipment require tuning up

- Updating building documentation to reflect current building usage and any equipment change outs
- Establishing an indoor air quality program for the building
- Assessing operator training needs annually

8.2 Designing For Operation and Maintenance

Like commissioning, successful operation and maintenance begins in the design phase of a project. Building owners have begun to recognize the importance of soliciting input from operation and maintenance staff during the early stages of building design. Building operation and maintenance staff can make design recommendations that facilitate good operation and maintenance practices. The more convenient it is for staff to perform regular checks and maintenance on building systems, the better building performance needs can be met and costly maintenance can be avoided. Examples of some design recommendations to help simplify operation and maintenance 8 are:

- Provide ground floor access to the chiller room through a connected loading dock
- Provide one or more roll-up doors of sufficient size to permit removal and replacement of chillers without having to disassemble equipment
- Provide sufficient clearance on all sides of the chiller to perform all maintenance
- Install hoist or crane equipment over banks of chillers
- Install sufficient valves to permit the isolation of an individual chiller without having to shut down the entire air conditioning system
- Install walkways around elevated equipment
- Provide roof access with adequate openings via stairs, not ladders

In addition, during the design stage the installing contractor's responsibilities concerning operation and maintenance should be clearly detailed in the project contract specifications, so that the contractor can adjust the bid price accordingly. For instance, specifications should explicitly state that contractors will be required to provide comprehensive operation and maintenance manuals for equipment and provide training for staff.

8.3 Operation and Maintenance Manuals

Operation and maintenance manuals for each piece of equipment are prepared by the contractor. The commissioning agent reviews each manual for compliance with the specifications as part of the commissioning process. Because manuals lose their usefulness if they are not kept up to date, any pages added to them, such as checklists or preventive maintenance work orders, must be included in each copy. Operation and maintenance manuals are useful as a reference tool for current facilities staff. They also can be used as a training resource for new staff.

8.4 Training

Perhaps the most essential component of operation and maintenance is training. Unless building operators and managers are given the skills to perform quality operation and maintenance practices, there is no hope that a building will continue to perform optimally.

As with all training, instruction should be structured to meet the needs of building operator staff. Training session topics ideally should be specified in the bid documents.

By videotaping each training session, including the hands-on startup and shutdown procedures for equipment, building operation staff gain a permanent and inexpensive onsite training aid. When new staff are hired, they can view the videos as part of their training.

For buildings where a facility manager without a technical background provides maintenance, the commissioning agent still can coordinate with contractors to ensure that the manager is educated about the capabilities, intended function and required maintenance of the building systems. This education should enable the facility manager to respond to occupant complaints in a manner that doesn't circumvent the systems' design intent. Training also should include a list of resources for the manager to call for maintenance assistance when necessary.

Once a building is operating and occupied, problems occasionally will develop that were not apparent during the commissioning process. These problems often occur during the first year of operation after construction or renovation. Sometimes the service contractor or operating staff can effectively troubleshoot and solve the problem. However, if a problem becomes chronic (for example, repeated comfort complaints), or if operating staff are unable to solve a problem in a reasonable amount of time, the owner should request expert troubleshooting assistance.

Because the commissioning agent and design engineer are very familiar with the building systems, the owner may want to consider contracting with one and/or both of them for the first year of operation to provide troubleshooting assistance on an as-needed basis. This contract could be written in a "fee-for-service" or an "amount-not-to-exceed" manner. Owners may find that it is more cost-effective to purchase troubleshooting services from the agent or engineer, because their knowledge of the building systems and design saves them time in diagnosing problems.

In the long run, owners also may find it beneficial to train operation and maintenance staff in energy accounting. In addition to tracking the building's energy use, energy accounting also can indicate when problems or potential problems exist with equipment operation.

8.5 Energy Management Control Systems

Many commercial buildings now use energy management control systems (EMCSs) or digital building management systems to improve building efficiencies. These systems also have the capability to assist with the commissioning process. A quality EMCS that includes data points for diagnostic purposes can assist the commissioning agent in diagnosing controls problems. Prior to its use as a commissioning tool, the EMCS itself should be commissioned. Features that improve EMCS usefulness in commissioning 9 include:

- Graphical user interface
- Capability to automatically download data when system memory starts to fill up

• Capability to specify starting times for trending requested parameters

• Capability to create time-series plots of up to eight parameters simultaneously

• Capability for the operator to "zoom in" on a plotted time period by drawing a box around the region of interest

• Capability to plot one or more parameters against another (x-y plots)

These features allow for quick data analysis. They also reduce the training time for an operator to collect commissioning data. Owners who are installing a new EMCS system should consider listing specific EMCS points that will be used for commissioning in the construction documents and the commissioning plan.

8.6 Building Commissioning Tools

Each owner or agency should develop or acquire a list of building commissioning resources that includes such items as:

- Language for including commissioning in RFPs
- Sample commissioning specifications for large facilities
- Directory of firms providing commissioning services
- Tips for project managers on managing the commissioning process
- Sample commissioning plan
- Boilerplate pre-functional and functional tests for selected equipment
- Bibliography of commissioning resources. [11]

CHAPTER 9

The Future of Building Commissioning

9.1 National Strategy

Commissioning is currently not a typical component of the new construction and renovation processes. Nor is it in frequent use as a means to optimize the performance of existing equipment. However, as both the infrastructure and the market for building commissioning grow, there is a push by many stakeholders to developing a national commissioning strategy. This strategy would seek to identify opportunities for business growth and development and to overcome the obstacles that have prevented commissioning from becoming "business as usual." The U.S. Department of Energy (DOE) is very interested in making sure that its efforts to promote commissioning build upon and enhance the efforts of other organizations. To further integrate commissioning into the mainstream, DOE is supporting the development of a national strategy to promote commissioning. The goals of this effort are to: 1) map the current state of commissioning activities in the United States; 2) identify gaps and needs for the commissioning market; and 3) develop recommendations for addressing these gaps and needs.

9.2 Demand

Owners are the primary market and direct beneficiaries of commissioning services. Early adopters share the perspective that they operate and manage their buildings as long-term investments. They purchase the technical knowledge and facilitation skills of a

commissioning authority to integrate quality assurance processes into standard construction and building operation practices.

Government agencies (Federal, State, Local) are currently (and will continue in the future to be) the leaders in implementing building commissioning. Federal government agencies as property owners are required to develop a commissioning plan for their buildings under the U.S. Energy Policy Act of 1992 and Executive Order 12902 (1994). Together these directives mandate that energy consumption in Federal buildings be reduced 30 percent by the year 2005 from 1985 levels. The U.S. General Service Administration recently began developing a comprehensive strategy to integrate commissioning into its nationwide design and construction program. Several state and local governments also have adopted the practice for their buildings.

In the private sector, early advocates of building commissioning include such major corporations as Westin Hotels, Boeing, Chevron, Kaiser Permanente, Disney Development Corporation, and Target, as well as numerous property owners who participated in utility-sponsored programs. Small commercial buildings appear to comprise only a minor portion of the commissioning market. The reasons for this include: the inherent fixed costs of commissioning relative to project budgets, the fact that smaller facilities are usually constructed and operated on tight budgets, and the lower value many owners place on commissioning smaller equipment.

9.3 Commissioning Infrastructure

Below are selected findings from an industry survey conducted for the Electric Power Research Institute. They indicate the present infrastructure for providing building commission services is developing as demand increases:

- Nationally, firms providing these services span many different business types and sizes, and few firms provide commissioning as a primary business.
- The market for commissioning/diagnostic services is growing among all building types as owners learn more about the benefits available through early investigation and correction of building problems.
- Leading firms expect this growth to continue as owners experience the benefits of improved building quality control, complex system performance, indoor air quality, and operational efficiency.
- The service commonly falls under the umbrella of engineering, architecture, testing and balancing, or design-build services, with engineering firms predominating.
- Commissioning services are available to a limited extent in all regions of the United States and for various commercial building sectors (office and retail, schools, universities, hospitals and laboratories, government facilities, and others).
- Commissioning of existing buildings provides firms with an opportunity to work with their customers throughout the lifetime of their facilities.

There are many national and regional organizations that provide commissioning support services to the building industry. These services are grouped into the following categories:

- **Technical and Demonstration Services** including research demonstration projects that involve on-site testing and diagnostics; development of tests and commissioning tools; documentation of case studies; and metering and data collection. Examples of organizations providing and/or funding these types of services include the California Institute for Energy Efficiency, the New York

State Energy Research and Development Authority (NYSERDA), and U.S. national laboratories (LBNL, ORNL, and PNNL).

- **Information and Research Services** including market research; identification of industry best practices; program design; and development and distribution of specifications, guidelines, informational materials, directories, and case studies. Examples of organizations supporting these services include professional associations such as American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the Florida Design Initiative (FDI), the Northwest Energy Efficiency Alliance (the Alliance), Portland Energy Conservation, Inc. (PECI), and numerous utilities.

- **Educational and Training Services** including development of course curriculum and offering training workshops and seminars. Examples of organizations providing these services include workshops offered by ASHRAE, the Association of Physical Plant Administrators (APPA), the Association of State Energy Research and Technology Transfer Institutions (ASERTTI), FDI, PECI, National Environmental Balancing Bureau (NEBB), NYSERDA, and the University of Wisconsin. In addition, to these workshops and seminars, government agencies, utilities and other organizations have funded the National Conference on Building Commissioning (NCBC) since 1993.

The federal government also is quite active in developing these support services. Department of Energy's (DOE) Rebuild America Program, the Federal Energy Management Program (FEMP), and the U.S. General Services Administration have each developed a commissioning booklet targeted toward their owner audiences. FEMP has also funded the development of comprehensive commissioning plans and guide specifications for construction documents and a number of commissioning demonstration projects. DOE is cooperating with the national laboratories on several projects. The U.S. Environmental Protection Agency's (EPA) Energy Star Buildings Program includes

commissioning as a part of its tune-up component and EPA and DOE encourage commissioning as part of their building-labeling program.

9.4 Market Potential

A comprehensive study of commissioning's market potential has not been conducted to date. The Northwest Energy Efficiency Alliance is currently assessing the market for commissioning services in the Northwest, and the results of this study should be available in late 1998. At present, it is estimated that less than 5% of all new construction and less than 0.03% of existing buildings are commissioned each year. These estimates are based on existing building and new construction data from the Commercial Buildings Energy Consumption Survey (CBECS) and analysis of savings and cost data from 175 commissioning case studies. To provide a perspective of the potential market a preliminary estimate for commissioning is summarized as follows:

Existing Buildings: If 1% of all existing commercial buildings greater than 25,000 square feet are commissioned annually, the following could result:

- 285 million square feet per year of commissioned space
- $48.4 million annual cost ($0.17/square foot)
- 3,730 billion Btu annual savings (12% of total bill), accumulating
- $46 million annual energy savings, accumulating
- Payback in slightly more than one year from energy alone
- Potential workload to sustain 570 full-time commissioning providers

New Construction: If 7% of all new buildings greater than 25,000 square feet are commissioned, the following would result:

- 43.8 million square feet per year of commissioned space
- $18.4 million annual cost ($0.42/square foot)

- 341 billion Btu annual savings (8% of total bill), accumulating
- $4.3 million annual energy savings, accumulating
- Payback in just over four years from energy alone
- Potential workload to sustain 200 full-time commissioning providers

Thus, there is a large market potential for new and existing building commissioning services. The large market coupled with the low number of experienced firms providing these services, results in a substantial opportunity for new entrants. An important aspect of this emerging industry from the owners' perspective will be the ability to qualify a firm and assess its capability to deliver the commissioning services as specified.

9.5 Overcoming the Barriers

Even with the many proven benefits to owners, commissioning has not reached the mainstream market. Interviews with commissioning providers, consumers and advocacy groups found that three main obstacles stand in the way of owners commissioning both new and existing facilities:

- A lack of awareness of commissioning by building owners, construction managers and design professionals
- A perception that commissioning is an extra up-front cost that introduces an unnecessary layer into the normal construction process
- Insufficient cost/benefit data to substantiate the contributions of commissioning to building construction and operation

In order to increase the demand for commissioning, these barriers must be overcome. Much of the existing commissioning case study information lacks the quantitative rigor needed to convince some owners and other target groups of the merits of commissioning.

Information is needed to respond to owners' frequently asked question: "Why should I pay 'extra' for commissioning?" Proposed action items include:

- Perform a quantitative cost-benefit analysis of commissioning relative to non-energy benefits. The study should establish the link between commissioning and the indoor environment and then bridge to productivity from the many existing and in-process studies linking indoor environment to productivity. The study should also address the construction process issues of change orders, litigation, construction time-line, callbacks, feedback loop, etc. This study should look at issues that affect the construction parties as well as the owners.

- Organize existing cost/benefit case studies for general distribution (see action item under Develop Marketing Materials below).

The national labs as well as non-profit advocacy groups (ASHRAE, NIST, PECI, TAMU Energy Systems Laboratory) are candidates for the task of quantifying the costs and benefits of commissioning. The Federal Government should make its own building data available to this study. Information on buildings commissioned under the DOE Rebuild America program, the EPA Energy Star® program, and General Services Administration's (GSA's) commissioning program, as well as any federal buildings that are commissioned should be provided to the labs for this research. [13]

9.6 Recommendation Actions

The greatest national need (though it may vary by region) is simply to increase the awareness of commissioning among owners, as well as among design professionals, contractors, vendors, and installers. Even without hard cost-benefit data, sufficient information exists to convince many owners of the benefits of commissioning for their

projects. Providing information to owners on how they begin a commissioning project or program is important, as part of increasing awareness. Increasing owner awareness involves: distributing marketing and resource materials; educating owners through workshops, presentations and conferences; and publishing commissioning articles in trade journals. Professional associations and insurance companies are potential allies in these efforts.

- Network with owner professional associations (such as BOMA) and other trade associations to encourage them to promote commissioning to their memberships.

- Enlist the support of insurance companies that serve both owners and industry professionals. Because commissioning can reduce claims resulting from improper or inadequate equipment performance and owner dissatisfaction, insurance companies have a stake in promoting the concept to their insurers.

Building Commissioning can be a valuable tool for both public and private building owners to improve the overall performance of their building and save valuable resources.

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Energy Efficiency and Renewable Energy Network
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The American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.
ASHRAE

http://www.ecw.org/tc99/

APPENDIX A

Glossary

Basic Glossary of Terms

Basis of Design Document: the document that records the foundation for calculations, decisions, schemes and product selections to achieve expected performance relating to the owner's requirements and to satisfy applicable regulatory requirements, standards and guidelines.

Building Systems: the architectural, structural, mechanical and electrical systems along with their respective subsystems, equipment and components.

Commissioning: the quality process for achieving, validating and documenting the performance of systems, subsystems and equipment to meet the basis of design and for preparing facility personnel for maintenance and operation.

Commissioning Authority: the designated entity who plans, coordinates and oversees the commissioning process.

Commissioning Plan: the overall document that outlines the organization, scheduling, allocation of resources and documentation pertaining to the commissioning for the individual facility.

Commissioning Report: the document that records the results of the commissioning process.

Commissioning Specification: the contract document that describes in detail the construction and acceptance phases of the commissioning process.

Commissioning Team: the various parties responsible for working together in carrying out the commissioning process under the direction of the commissioning authority.
Design Intent Document: the document describing in detail the measurable performance requirements of the facility developed from the facility program.

Design Team: the various parties responsible for working together in providing for the design and preparation of contract documents for the various building systems of the facility.

Facility Program: the document describing in detail the ideas, goals, concepts, requirements deemed important by the facility owner.

F*unctional Verification*: the process of determining that a component is correctly manufactured, installed, started, adjusted and prepared for the performance tests.

Guide: recommended language intended to be broadly applicable.

Model: recommended document intended to be broadly representative.

Performance Verification: the process of determining the ability of a system to function and deliver services in accordance with the design intent.

Test Procedures: the detailed, sequential steps required to set parameters and conditions required to test system functionality and performance.

Validation: the establishment of documented evidence which provides a high degree of assurance that a system will consistently perform in accordance with the design intent.

Verification: the implementation of the full range of reviews and tests carried out to determine if systems and interfaces between systems operate in accordance with the design intent.

APPENDIX B

Part1:

Solicitation for Commissioning Agent Services

Solicitation for Commissioning Agent Services

BACKGROUND

____________________________ (Owner) is seeking the services of a qualified commissioning agent/firm for a new commercial construction project. The project is a ___________ gross sf, ___ story, Class ___ [type] ___________ building in [city & state] ___________, _________, with a project budget of $______ million. The facility is expected to be comprised of ____% office space, ____% retail, _____ parking garage, and _____% medical laboratory .

The project has gone through the programming phase, with a programming report available for review. The balance of design is expected to be completed by _________________ and construction started by _____________, with a final occupancy date of _________________.

If the project is already designed, include detailed descriptions of the systems in the building that will be commissioned.

The management structure is traditional "design and spec" with full design documents and specifications to be developed by an architectural firm. The construction documents will be let out to bid and a general contractor will be hired to complete the construction. The design team will have limited construction oversight. The Owner's primary construction representative on-site will be provided by the separately contracted services of a construction management firm. The commissioning agent will report to the construction manager.

If the project is not a design and spec, describe the structure and the oversight and lines of responsibility for the A/E, commissioning agent and owner's representative. **If you are providing the CA with more detailed design phase commissioning requirements, a design phase model plan, sample commissioning construction specifications and a model construction phase commissioning plan for reference, you can delete out the redundant areas of this RFP.**

SCOPE OF WORK

The Owner is committed to commissioning this facility to ensure that all systems are complete and functioning properly upon occupancy and that facility staff have adequate system documentation and training. Commissioning consists of systematically documenting that specified components and systems have been installed and started up properly, and then functionally tested to verify and document proper operation through all modes and conditions. In addition, owner-personnel training will be verified and final project operations and maintenance (O&M) documents will be reviewed for completeness.

The following is a summary of the commissioning process which the Owner intends to have implemented on this project. The proposer is free to suggest changes and improvements to this process. However, for this proposal the following process will be assumed.

Commissioning Process During Design

A summary of the commissioning process during design is:

1. A design phase commissioning plan is developed by the commissioning agent (CA).
2. The design team members perform their normal functions in addition to the commissioning related tasks of documenting the design intent.
3. The CA performs a focused review of design development.
4. The CA develops the draft commissioning plan for the construction phase.
5. The CA develops commissioning specifications for the construction documents, with review by the design team, for inclusion in their construction specifications.
6. The design team develops in-depth design documentation, including design intent, basis of design and full sequences of operation for inclusion in the construction documents.
7. The CA performs a design review at 50% and 95% completion of the drawings and specifications.
8. The CA updates the original draft of the commissioning plan for the construction phase.

Commissioning Process During Construction and Warranty

A summary of the commissioning process that the Owner will follow during construction is:

1. A commissioning plan is developed by the commissioning agent.
2. A scoping meeting is conducted by the CA where the commissioning process is reviewed with the commissioning team members.
3. Additional meetings will be required throughout construction, scheduled by the CA with necessary parties attending, to plan, scope, coordinate, and schedule future activities and resolve problems.
4. Equipment documentation is submitted to the CA during normal submittals, including detailed start-up procedures.
5. The CA works with the Subcontractors (Subs) in developing start-up plans and start-up documentation formats, including providing to the Subs prefunctional checklists to be completed during the startup process.
6. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with prefunctional checklists being completed before functional testing.
7. The Subs, under their own direction, execute and document the prefunctional checklists and perform startup and initial checkout. The CA documents that the checklists and startup were completed according to the approved plans. This may include the CA witnessing startup of selected equipment.
8. The CA develops specific equipment and system functional performance test procedures. The Subs review the procedures.
9. The procedures are executed by the Subs, under the direction of, and documented by the CA.
10. Items of non-compliance are corrected at the Subs' expense and the system retested.
11. The CA reviews the O&M documentation for completeness.
12. Commissioning is completed before Substantial Completion.
13. The CA reviews, pre-approves and coordinates the training provided by the Subs and verifies that it was completed.

14. Deferred and seasonal testing and performance evaluation is conducted, as specified or required.

Commissioning Agent Responsibilities

The proposer is free to suggest changes and improvements to following task list. However, for this proposal the following tasks will be assumed.

The commissioning agent/firm (CA) will have the following responsibilities:

The CA is not responsible for design concept, design criteria, compliance with codes, design or general construction scheduling, cost estimating, or construction management. The CA may assist with problem-solving or resolving non-conformance or deficiencies, but ultimately that responsibility resides with the general contractor and the A/E. The primary role of the CA is to develop and coordinate the execution of a testing plan, observe and document performance—that is determine whether systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.

Programming and Conceptual Development Phase
—None—

Schematic Design and Design Development Phase
1. Coordinate the commissioning work during design
2. Develop a design-phase commissioning plan, using the draft or "boilerplate" version provided by the Owner or other approved models.
3. Perform a focused design review at the end of Design Development, as described in Exhibit 1.
4. Assist design team members in developing their portions of the design intent. Approve their submissions.

Construction Documents Phase
1. Coordinate the commissioning work during this phase.
2. Perform a focused review of the drawings and specifications when 50% and 95% complete, as described in Exhibit 2.
3. Assist, review and approve the development of the design intent and operating parameters documentation by all design team members.
4. Develop a draft project-specific commissioning plan for the construction phase, using the "boilerplate" version provided by the owner or other approved models.
5. Develop full commissioning specifications for all commissioned equipment listed below using one or more of the following documents as a guide for content, rigor and format: 1) *Model Commissioning Plan and Guide Specifications*, USDOE/FEMP; Portland Energy Conservation, Inc. (PECI). Available in electronic and hard copy form from National Technical Information Service (NTIS) at 1-800-553-6847 and on the internet through PECI, http://www.teleport.com/~peci. 2) *Facility Design Information Manual,* Engineering Services, University of Washington. Available over the internet at http://weber.u.washington.edu/~fsesweb, under Vol. 2 Division 17 Commissioning. 3) *The*

HVAC Commissioning Process, ASHRAE Guideline 1-1989R. Available from ASHRAE at 404-636-8400.
The commissioning specification will include a detailed description of the responsibilities of all parties included in the commissioning process; details of the commissioning process; reporting and documentation requirements, including formats; deficiency resolution; prefunctional checklist and startup requirements; the functional testing process; specific functional test requirements, including testing conditions and acceptance criteria for each piece of equipment being commissioned.

6. Have the commissioning specifications approved by the A/E team and included in the A/E construction specifications.

<u>*Construction and Acceptance Phase*</u>

1. Coordinate and direct the commissioning activities in a logical, sequential and efficient manner using consistent protocols and forms, centralized documentation, clear and regular communications and consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
2. Coordinate the commissioning work and, with the general contractor (GC) and construction manager (CM), ensure that commissioning activities are being scheduled into the master schedule.
3. Revise, as necessary, the current draft of the construction phase commissioning plan developed during design.
4. Plan and conduct a commissioning scoping meeting.
5. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
6. Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
7. Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
8. Write and distribute prefunctional tests and checklists.
9. Develop an enhanced start-up and initial systems checkout plan with Subs.
10. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
11. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
12. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
13. Approve prefunctional tests and checklist completion by reviewing prefunctional checklist reports or by direct site observation.
14. Approve systems startup by reviewing start-up reports and by selected site observation.
15. Review testing, adjusting and balancing (TAB) execution plan.
16. Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.

17. Approve air and water systems balancing by spot testing and by reviewing completed reports and by selected site observation.
18. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data-logger monitoring or manual functional testing. Submit to CM for review, and approval if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
20. Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
21. Maintain a master deficiency and resolution log and a separate testing record. Provide to the CM written progress reports and test results with recommended actions.
22. Witness performance testing of smoke control systems by others and all other owner contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document and include in Commissioning Record in O&M manuals.
23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
24. Oversee and approve the training of the Owner's operating personnel.
25. Compile and maintain a commissioning record and building systems book(s).
26. Review and approve the preparation of the O&M manuals.
27. Provide a final commissioning report.

Select the warranty period services desired below.

Warranty Period

1. Coordinate and supervise required seasonal or deferred testing and deficiency corrections and provide the final testing documentation for the commissioning record and O&M manuals.
2. Return to the site at 10 months into the 12 month warranty period and review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. Also interview facility staff and identify problems or concerns they have with operating the building as originally intended. Make suggestions for improvements and for recording these changes in the O&M manuals. Identify areas that may come under warranty or under the original construction contract. Assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.
3. Assist in the development of a preventative maintenance plan, a detailed operating plan or an energy and resource management plan.

Assumptions

It is assumed that the A/E will provide adequate written design intent, basis of design and full sequences of operation for all equipment and systems for the O&M manuals and for the commissioning agent to use in writing functional tests. It is also assumed that the contractors will execute the functional testing of equipment, coordinated and documented by the commissioning agent, using forms provided by the commissioning agent.

Systems To Be Commissioned

The following systems, including all components and controls, will be commissioned:

Delete and add systems as desired.

1. Central building automation systems, including linkages to remote monitoring and control sites (this excludes any security-related control systems or interlocks).
2. All equipment of the heating, ventilating and air conditioning systems.
3. Medical laboratory clean room hoods and pressurization
4. Refrigeration systems
5. Life safety systems (fire alarm, egress pressurization, fire protection)
6. Domestic and process water pumping systems
7. Emergency power and uninterruptible power supply (UPS) systems
8. Lighting control systems
9. Communication and paging systems

The following outlines the level of effort expected for each commissioned system:

The CA shall review the design documentation (design intent, basis of design and sequences of operation) for completeness. The CA shall develop prefunctional checklists for the installing contractors to include in their startup and initial checkout. The CA shall develop detailed written test procedures for guiding and documenting performance during functional testing.

The functional testing shall include operating the system and components through each of the written sequences of operation and other significant modes and sequences, including startup, shutdown, unoccupied mode, manual mode, staging, miscellaneous alarms, power failure, security alarm when impacted and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during prefunctional checklisting by the installing contractors and spot checked by the commissioning agent during functional testing.

Tests on respective HVAC equipment shall be executed during both the heating and cooling season. However, some overwriting of control values to simulate conditions may be allowed, if used judiciously. The central plant shall have its efficiency bench-marked for later use by operations staff. Functional testing shall be done using conventional manual methods, control system trend logs or stand-alone dataloggers, to provide a high level of confidence in proper system function, as deemed appropriate by the commissioning agent and the Owner.

DESIRED QUALIFICATIONS

It is desired that the person designated as the site commissioning agent satisfy as many of the following requirements as possible:

1. Have acted as the principal commissioning agent for at least three projects over 100,000 sf.

Increase or reduce the size of required project experience, depending on your project.

2. Have extensive experience in the operation and troubleshooting of HVAC systems, energy management control systems and lighting controls systems. Extensive field experience is required. A minimum of five full years in this type of work is required.
3. Knowledgeable in building operation and maintenance and O&M training.
4. Knowledgeable in test and balance of both air and water systems.
5. Experienced in energy-efficient equipment design and control strategy optimization.
6. Direct experience in monitoring and analyzing system operation using energy management control system trending and stand-alone datalogging equipment.
7. Excellent verbal and writing communication skills. Highly organized and able to work with both management and trade contractors.
8. Experienced in writing commissioning specifications.
9. A bachelors degree in Mechanical Engineering is strongly preferred and P.E. certification is desired, however, other technical training and past commissioning and field experience will be considered.
10. The majority of the required expertise for this project must be part of the skill and experience set of the prime firm making the proposal. A member of that firm will be the designated Commissioning Agent. The Commissioning Agent must be fully qualified to commission most of the above listed systems. If the Commissioning Agent or prime firm does not have sufficient skills to commission a specific system, the prime firm shall subcontract with a qualified party to do so. That party's qualifications shall be included and clearly designated in the response to this RFP.
11. The Commissioning Agent will be an independent contractor and not an employee or subcontractor of the General Contractor or any other subcontractor on this project, including the A/E.

If the project is large (>200,000 sf or so), include the following language and other language as appropriate. Specifiy project sizes, etc.

It is desired that the prime commissioning firm have a designated project manager with the following qualifications. This person may also be the designated primary site commissioning agent.

1. Experienced in the design process of large projects > __________ sf.
2. Experienced in working with the construction management and process protocols of large buildings and projects.
3. Experienced in managing multi-year projects.

INSTRUCTIONS TO PROPOSERS

A proposer must propose to execute all phases of the commissioning in a single proposal. However, the proposer will provide separate prices for the design and construction/warranty phases shall be provided.

The proposal shall be limited to 15 single-sided pages, including graphics. A letter of introduction, section dividers, detailed resumes and the sample work products of item five below are not included in this limit.

The proposal must be signed by an officer of your firm with the authority to commit the firm.

1. Fill out the attached Commissioning Firm Experience form, including the Project Experience Listing form (Exhibits 4 and 5).
2. List the key individual who will be the commissioning agent for this contract and describe his or her relevant qualifications and experience. This information is required in addition to any detailed resumes the proposer submits. The contract will require that this individual be committed to the project for its duration.
3. List the relevant experience of project management, supporting staff and subconsultants, including detailed resumes, with the fraction of expected hours for each. Project management, supporting staff and subconsultants shall provide less than ___% of the total time on the project.

The above fraction should range from 20 to 50%. Larger, more complex projects and projects with a variety of primary system types will have fractions in the upper range.

4. Provide project and professional references and experience for three to five commissioning projects for which the proposer was the principal commissioning agent in the last three years. Include a description of the project, including square footage and systems commissioned. Identify when the proposer came into the project. *Describe* the involvement of each individual on the proposer's team in the projects for the following areas: systems *and components* commissioned, specification writing, design review, commissioning plan development, functional testing procedures and forms, coordinating and overseeing functional testing, actually performing the functional testing (hands-on), troubleshooting involvement, project management, O&M manual reviews and O&M training. Provide this data on the attached Commissioning Project Experience Listing form. For each project, attach a sheet that includes the name and telephone number of the owner's project manager, construction manager, facility administrator of the building, the mechanical designer, the controls contractor site project manager, the mechanical contractor and electrical contractor.
5. Describe any experience of the proposer's team in the following areas. List the each party's involvement.
   a) traditional test and balance;
   b) commissioning laboratories;
   c) O&M experience;
   d) energy-efficient equipment design and control strategy optimization;
   e) life cycle costing; and
   f) experience in environmental sustainable design.
   g) project and construction management

Delete items in the above list for areas that you do not want the commissioning agent to provide specific task work.

6. Describe your proposed approach to managing the project expertly and efficiently, including your team participation. Describe what approach you will take to integrate the commissioning into the normal design and construction process in order to minimize potential time delays. Describe what you will do to foster teamwork and cooperation from contractors and designers and what you will do to minimize adversarial relationships. Describe how you intend to determine the appropriate level of commissioning effort for the various systems and equipment. Describe how your work will facilitate the use of your product as a prototype

which may be subsequently used by the Owner in future projects, including access to the electronic versions of all documents and forms.

7. As an attachment, provide the following work products that members of the proposer's team wrote. List the team member who actually wrote the document and the projects on which they were used. Work from the designated commissioning agent is highly preferred.
   a) commissioning plan;
   b) commissioning specifications; and
   c) an actual functional test procedure form that was executed.
8. Provide both an estimated total fee to accomplish the work and an hourly rate for each team member if the project is set up on a time-and-materials basis. The Owner will negotiate with the selected proposer and may contract on a fixed fee or time and materials basis.

SELECTION CRITERIA

Scale the weights below as desired.

The submitted proposals will be reviewed and ranked according to the following (items from the above numbered list):

1. & 2. Key individual experience	20 points
3. Staff and subconsultant experience	10 points
4. Similar project experience	15 points
5. Team experience in related skill areas	15 points
6. Management approach	20 points
7. Work examples	10 points
8. Fee proposal	10 points
	100 points

Reference checks will not be scored individually, but may be used to supplement all categories. The Owner reserves the right to eliminate or change the weight of extremely high or extremely low fee proposals.

SUBMISSION AND SELECTION

Consultants will submit __________ ( ) copies of the written proposal, to be received in the Owner's office at [address____________________] by [date and time__________________________]. Late proposals will not be accepted.

Review and selection process ....

Requirement of personal interview for finalists..........................

PROTESTS

Wording as required...............................

LIMITATIONS AND PROVISIONS

Wording on right to reject, to seek clarifications, to negotiate a final contract. Cost of proposal preparation not reimbursable. Primary contact for questions. Other necessary legal language, etc......................................

Date due, where to submit, number of copies, etc.

MINIMUM REQUIREMENTS FOR CONTRACT EXECUTION

General Conditions.

Misc. as required....................

Insurance

The commissioning firm shall obtain, at the firm's expense, and keep in effect during the term of the project, ... liability insurance covering .... with the following limits .... etc.

Change in Personnel

If the commissioning firm's personnel or subconsultants change for this project, the Owner must review and approve the replacement personnel, in advance. The replacement personnel shall have, at minimum, equivalent qualifications as the original personnel.

...........List other legal requirements as required ....

Exhibit 1

Check the areas for which you want the commissioning firm to provide input.

FOCUSED DESIGN DEVELOPMENT REVIEW ELEMENTS

The following checked areas will be reviewed by the commissioning agent.

Design Area	Review Description
____ *Commissioning facilitation*	Input regarding making the building easier to commission (see Exhibit 3)
____ *Energy Efficiency*	General efficiency of building shell, building layout, HVAC system types, lighting system type, etc.
____ *Operations and Maintenance (O&M).*	How building O&M can be made easier (accessibility and system control, etc.)
____ *Indoor Environmental Quality (IEQ)*	How thermal, visual, acoustical comfort or air quality can be improved
____ *Functionality for Tenants*	How the design can be changed to improve functionality for the occupants
____ *Environmental Sustainability*	How the building materials and systems and landscaping can create less of an impact on the environment
____ *Life Cycle Costs*	Life cycle assessment of options relative to energy efficiency, O&M, IEQ or functionality

Exhibit 2

Check the areas for which you want the commissioning firm to provide input.

FOCUSED 50% AND 95% DESIGN REVIEW ELEMENTS

The commissioning agent will perform a review at 50% and 95% design construction documents completion comprised of the following checked areas:

Design Area	Review Description
___*Commissioning facilitation*	Input regarding making the building easier to commission (see Exhibit 3).
___*Component energy efficiency*	Review for adequacy of the efficiency of bldg. shell components, HVAC systems and lighting systems.
___*Control system & control strategies*	Review ___HVAC, ___lighting, ___fire control, ___emergency power, ___security control system, strategies and sequences of operation for adequacy and efficiency.
___*Operations and maintenance*	Review for effects of specified systems and layout toward facilitating O&M (equipment accessibility, system control, etc.).
___*Indoor environmental quality*	Review to ensure that systems relating to ___thermal, ___visual, ___acoustical, ___air quality comfort, ___air distribution are in accordance with the design intent.
___*Environmental sustainability*	Review to ensure that the ___building materials, ___landscaping, ___use of water resources, ___waste management are in accordance with the design intent.
___*Functionality for occupants*	Review to ensure that the design meets the functionality needs of the occupants.
___*Life cycle costs*	Perform a ___qualitative, ___quantitative life cycle assessment of the primary competing systems relative to ___energy efficiency, ___O&M, ___IEQ, ___functionality.
___*O&M documentation*	Verify that building O&M plan and documentation requirements specified are adequate
___*Training*	Verify that operator training requirements specified are adequate.
___*Commissioning specifications*	Verify that bid documents adequately specify building commissioning and that there are adequate monitoring and control points specified to facilitate commissioning and O&M (trending capabilities, test ports, control points, gages and thermometers).

Exhibit 3

COMMISSIONING FACILITATION REVIEW

One of the primary tasks for the commissioning agent is reviewing the design documents to facilitate commissioning during construction. The construction-phase commissioning process can be made easier and more effective if certain features are included in the design. The added up-front costs for most of these features can be justified because they reduce the cost of commissioning, allow for a better commissioning job and reduce the O&M costs for the building. Below is a list of some of these features. Not all are addressed in detail in the design development review. However, they should be brought to the attention of the A/E at this time, so that they can be incorporated during the construction documents phase. The review is not expected to be limited to only those issues listed below.

- Clear and rigorous design documentation, including detailed and complete sequences of operation.
- An HVAC fire and emergency power response matrix that lists all equipment and components (air handlers, dampers, valves, etc.) with their status and action during a fire alarm and under emergency power.
- Access for reading gages, entering doors and panels, observing and replacing filters, coils, etc.
- Required isolation valves, dampers, interlocks, piping, etc. to allow for manual overrides, simulating failures, seasons and other testing conditions.
- Sufficient monitoring points in the building automation system (BAS), even beyond that necessary to control the systems, to facilitate performance verification and O&M.
- Adequate trending and reporting features in the BAS.
- Pressure and temperature (P/T) plugs close to controlling sensors for verifying their calibration.
- Pressure gages, thermometers and flow meters in strategic areas to facilitate verifying system performance and ongoing O&M.
- Pressure and temperature (P/T) plugs at less critical areas or on smaller equipment where gages and thermometers would be over-kill.
- Specification of the location and criteria for the VAV duct static pressure sensor and chilled water differential pressure sensor.
- Adequate balancing valves, flow metering and control stations and control system functions to facilitate and verify reliable test and balance.
- Uniform inlet connection requirements to VAV terminal boxes.
- Clear and complete commissioning specifications for the construction phase.
- Complete O&M documentation requirements in the specifications.
- Complete training requirements in the specifications.
- Review entire document and building information management plan from design through construction and turnover to ensure adequacy and compliance with the owner's program.

Exhibit 4

COMMISSIONING FIRM EXPERIENCE

Company Name Contact Person Title

Address City State/Prov Zip/Postal Code

Telephone Fax E-Mail

Description of Business

Commissioning Activities

Percentage of overall business devoted to commissioning services ____________%

How long has the firm offered commissioning services ____________years

Average number of commissioning projects performed each year: ____________projects

Systems (technologies) for which firm has provided commissioning services (check all that apply) ■

- ❑ Pkg or split HVAC
- ❑ Chiller system
- ❑ Boiler system
- ❑ Energy Mgmt. System
- ❑ Variable Freq.Drives
- ❑ Lighting Controls
- ❑ Daylighting
- ❑ Electrical, general
- ❑ Electrical, emerg. power
- ❑ Envelope
- ❑ Fire/Life Safety
- ❑ Plumbing
- ❑ Commercial refrigeration
- ❑ Telecommunications
- ❑ Thermal Energy Storage
- ❑ Labs & Clean Rooms
- ❑ ____________

Number of registered professional engineers on staff who have directed commissioning projects: ______

The firm has provided commissioning services in the following: (check all that apply) ■

Building Sector	New Construction Major Renovation	Existing Building (Building Tune-up)	Equipment Replacement
Office	❑	❑	❑
Retail	❑	❑	❑
Grocery	❑	❑	❑
Hospitals	❑	❑	❑
Laboratories	❑	❑	❑
Schools	❑	❑	❑
Universities	❑	❑	❑
Federal, state, local gov't	❑	❑	❑
Industrial / Manufacturing	❑	❑	❑
Special purpose–prisons, museums, libraries, etc.	❑	❑	❑

Part 2:

Sample Guide Specifications

Commissioning Guide Specifications

Overview

1. General Overview

These commissioning guide specifications contain recommended language that describes both the requirements and the process to incorporate commissioning into larger construction or renovation projects. Significant process language is required because commissioning is new to many construction professionals. The specifications generally follow the ASHRAE document, *The HVAC Commissioning Process*, ASHRAE Guideline 1-1989R, final draft 1996, though significant additional detail, clarification and interpretation has been made.

The guide specifications are intended to be modified by the architect and design engineers (A/E) in consultation with the design phase commissioning agent, the project manager and the facility engineer, if known. The A/E shall modify other specification sections as necessary to reflect commissioning requirements applicable to the current project.

Abbreviations are used in the Specifications and are defined in Section 01040 and 17100, Part 1.

2. Management Scenarios

The specifications were developed for the construction management protocols of the owner, which include:

1. The construction manager (CM) is a subcontractor to the owner and represents the owner in the day-to-day activities and job coordination for the entire construction project.
2. The owner's staff project manager (PM) manages the CM.
3. The A/E's role during construction consists of the basic services of submittal review and periodic site observation. The A/E team is not significantly involved in performance verification or quality control. Therefore, its role in commissioning is limited to dealing with design and other problems identified during commissioning, attending selected commissioning team meetings, reviewing clarifications to the control sequences by the commissioning agent, reviewing selected functional test procedures, providing as-built design intent for the O&M manuals, and presenting at the first owner personnel training.

Other notable management and process information:

1. The specifications are applicable to a variety of commissioning agent (CA) hiring scenarios: CA hired by the CM, directly by the owner, by the general contractor (GC) or by the A/E.
2. The CA is the person directly coordinating and directing all commissioning activities on a day-to-day basis.
3. If the CA is hired by the GC or A/E, the CM will verify that the CA is properly executing the commissioning as per specification. In this case the CA reports directly to the CM.

4. If the CA is hired by the CM or directly by the owner, the verification of the CA's commissioning work in (3) is eliminated.

5. The subcontractors (under the GC) direct, execute and document their own startup and initial checkout, incorporating the CA's prefunctional checklists and the CA's review comments of their start-up procedures.

6. The CA develops the functional testing procedures and the subcontractors execute them under the direction, observation and approval of the CA. The CA documents the functional testing.

Specification Section 17100 provides some graphic illustrations of various management scenarios. Appropriate name substitutions can be made for the various parties involved, allowing the specifications to be applicable to other agencies or groups.

Test Engineer Scenario. There are guide specifications in the industry that use this scenario. These specifications do not. The following is a short explanation to prevent confusion. In the test engineer scenario, the contractor hires a test engineer who writes and executes the commissioning tests, etc. A person designated as the "commissioing agent" is hired by or is on the owner's staff. This commissioning agent is the line supervisor for the test engineer and acts as the owner's representative for commissioning issues. For comparison, the test engineer in the test engineer scenario, performs virtually all the tasks that the commissioning agent does under the *Model Commissioning Plan and Guide Specifications*. The commissioning agent in the test engineer scenario is analogous to the construction manager in the *Model Plan and Specs*. However, in the test engineer scenario, the commissioning agent must have considerably more commissioning experience than does the construction manager in the *Model Plan and Specs* scenario.

3. Scope

This draft of the commissioning specifications covers HVAC and automatic control systems for larger buildings. Future versions will cover electrical and other mechanical systems. However, Section 17100 describes the common requirements and processes that are applicable to all commissioned systems, not just HVAC and controls. The A/E can add systems to be commissioned without making any modifications to Section 17100, except for adding references to added systems. In general, these specifications assume that clear and complete design intent documentation was developed during the design phase. However, some language is included to handle cases when it is not.

4. Specification Sections and Responsibilities

The following describes the approach that was used to incorporate commissioning into the standard specification format.

1. The intent was to minimize redundancy and repetition whenever possible, and yet still have as many requirements for a given trade, in the trade's normal specification division and section. Specific commissioning *requirements* for a given trade are all listed in one place. However, the commissioning *procedures* to execute the requirements, many of which are common to all trades, are necessarily found in other sections. Cross references are used extensively to provide access to all procedures and requirements.

2. In all divisions with requirements that relate to commissioning, there are references to the specific commissioning requirements in other divisions.

   a. In Division 1, Section 00800, Suplementary Conditions, there is language providing a penalty for not completing commissioning on time.

   b. In Section 01040, Coordination, there is an introduction to commissioning, the commissioning agent and a reference to Division 17.

   c. Section 01300 Submittals, Section 01700 Project Close-out and Section 01730 O&M Data also contain references to Division 17.

   d. The trade sections of 15010 Mechanical General, Section 16010 Electrical General contain references to Division 17 and to the special commissioning sections within their respective divisions (15995; 16995).

3. The commissioning process details, the commissioning requirements that apply to all parties, and the specific responsibilities of the commissioning agent and non-trades, (construction and project manager) are included in a special Division 17, Commissioning.

4. A special commissioning section of Division 15, Section 15995 is used to specify common and specific commissioning requirements of all Division 15 contractors. In addition, the specific, unique responsibilities of Division 15 contractors are included in appropriate sections of Division 15 and 16 (e.g., 15950 controls, 15990 TAB).

5. Specific functional testing requirements are found in the Sections 15997 and 16997, Mechanical and Electrical Testing Requirements.

6. Specific prefunctional checklists are found in Sections 15998 and 16998.

7. Sample functional test procedures are found in Sections 15999 and 16999.

The following lists the sections included in the commissioning (Cx) guide specifications. Refer to Figure 1 for a graphical layout of the specification sections. A detailed table of contents is provided at the beginning of the major sections (15995, 17100).

00800 Supplementary Conditions	Provides for a penalty if commissioning is not completed by the Functional Completion milestone.

** If the commissioning agent is hired by the owner or construction manager, 01040a applies:*

01040a Coordination	Introduces commissioning and refers to Division 17.

** If the commissioning agent is hired by the general contractor, 01040b applies:*

01040b Coordination	Introduces commissioning, refers to Division 17 and requires that the GC hire a qualified CA.
01300 Submittals	Alerts all parties that additional detail in submittals may be required and directs to Division 17.
01700 Project Close-out	Defines Substantial Completion and Functional Completion milestones, relative to commissioning.
01730 O&M Data	Alerts all parties that O&M documentation may be more detailed and directs to Division 17.

15010	Mechanical General	Alerts the mechanical contractor of Cx responsibilities in 15995.
15950	Automatic Controls	Lists special requirements and alerts the controls contractor of the special requirements of the control contractor and control system in 15995.
15990	TAB	Alerts the TAB of Cx responsibilities in 15995.
15995	Mechanical Cx	Describes the Cx responsibilities of the mechanical, controls and TAB contractors and the prefunctional testing and start-up responsibilities of each. Points to 15997 for functional testing requirements.
15997	Mechanical Testing Requirements	Describes the specific functional testing requirements Division 15 equipment in the project.
15998	Mechanical Prefunctional Checklists	Provides the prefunctional checklists for use on this project, including items for Div. 15 and Div. 16.
15999	Mechanical Functional Tests–Examples	Provides example functional test procedures and formats for mechanical equipment.
16010	Electrical General	Alerts the electrical contractor of Cx responsibilities in 16995.
16995	Electrical Cx	Describes the Cx responsibilities of the electrical contractor.
16997	Electrical Testing Requirements	Describes the specific functional testing requirements for Division 16 equipment in the project.
16998	Electrical	Points to Section 15998 prefunctional checklists.
16999	Electrical Functional Tests–Examples	Provides example functional test procedures and formats for electrical equipment.
17100	Commissioning	Describes the commissioning process, responsibilities common to all parties, responsibilities of the A/E, CA, CM, PM, GC and Suppliers, focusing on the CA. The unique mechanical contractor, controls contractor, TAB and electrical contractor responsibilities are included in Div. 15 and 16.

5. Electronic Format

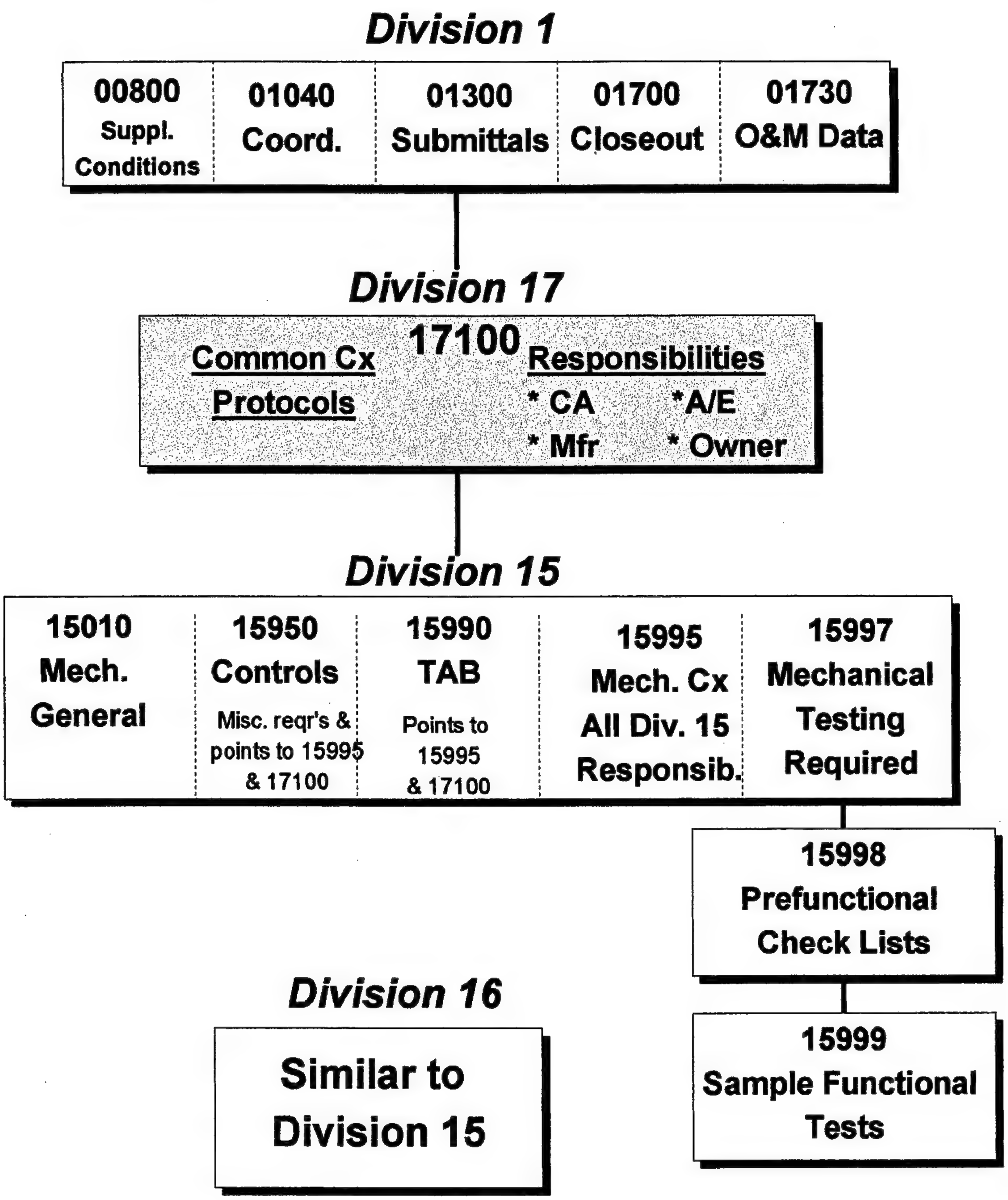
All sections have been included as separate files on diskette in Word 6.0 for Windows 3.1 with the following file name format. The version number refers to the specific file or section version, not the entire Guide Specification version.

[Section #. Version #] For example: file 15995.V02 is Section 15995 Version 2.

A complete listing of files is found in the overview of the entire document prior to Part I (file: all_ovr.v10).

Figure 1.

Specification Structure



Part 3:

Documenting Design Intent & Basis of Design

For Energy and Comfort Systems

Instructions for Documenting Design Intent and Basis of Design of Energy- and Comfort-Related Systems

1 Objective

This appendix presents a format for the building designers to use in documenting the design intent and fundamental operation of the building systems they have designed. Refer to Section 3 for a narrative on the need of a written design intent and clear sequences of operation and Section 5 for an example. The design-intent documentation requested here is primarily a narrative description of the building systems, what the objectives of the systems are, and how the systems will meet those objectives. This written documentation is intended for use by the designers, the commissioning agent, the installing contractors, and the building operators. This document does not constitute the required documentation and operations manual for these systems, but is a part of the O&M manuals.

The *design intent* provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner, resulting from the programming and conceptual design phases. The *basis of design* is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The format below merges the salient parts of the design intent and basis of design.

Following these instructions is a form that is used for structuring the format and content of the design documentation.

This design intent document format contains examples for the following issues, equipment, and systems.

1. General building design and function
   - Overview
   - Sustainable construction and environmental compatibility
   - Indoor environmental quality—thermal, air distribution, acoustics, air quality, visual quality
   - Landscaping
2. HVAC systems—general
   - Overview
   - Design conditions and load assumptions
3. Chiller system (chillers, cooling towers, pumps)
4. Boiler and heating water system
5. Roof top packaged system, including all components
6. VAV terminal units (cooling only)
7. VAV terminal units (reheat)
8. Heat recovery unit
9. Computer room AC unit
10. Daylighting controls
11. Lighting sweep control
12. Building automation system

13. Split air conditioner or heat pump
14. Emergency power system

The design documentation for components or systems not listed above should follow the general form and content of this document and should describe the system, its purpose, why it was chosen above others, how it functions, and how it relates to other components and the parameters for its operation and control, including detailed sequences of operation. For additional details, refer to *ASHRAE Guidelines 1-1989R The HVAC Commissioning Process,* ASHRAE, 1996.

The design intent document may be filled out by hand for applicable systems, with attachments when necessary, or by preparing an entirely new document using the electronic version as a template.

2 Design Documentation for This Building

Adequate documentation of the design intent and basis of design of the energy- and comfort-related systems in a building is rarely found in bid documents. It is vital, however, that design intent and sequences of operation be documented adequately. That documentation serves as the goal that testing and verification seek to achieve. In addition, the design-intent document provides valuable information over the life of the building to the different parties involved in operating, maintaining, and troubleshooting the building systems.

Following are the primary areas related to energy use and comfort for which the design intent should be defined. Under each area or building system is an outline of pertinent questions concerning what should be included in the design-intent documentation and where additional clarification is needed. Sequences of operation for all outlined dynamic systems and components should be documented. Attaching equipment manufacturers' sequences is acceptable, but these sequences will generally require additional narrative. Sample sequences are found in Section 5.

To the right of the heading for each section, the party responsible for providing the design intent is indicated, as is the phase of the design construction process during which design intent should be established. For example:

4.2 System Description Mech Engr *Design Dev*

The above sample heading indicates that the mechanical engineer or designer is responsible for developing the design narrative that follows the heading and that it should be completed during the design development stage. The responsible parties and design phases are sometimes abbreviated as in the table below. The phases of the design construction process are as follows.

Programming	Design team and the Project Manager meet with representatives of the occupuying agency or client and determine the floor area and occupancy requirements of the building.
Conceptual Design	Architect develops block diagrams, building sizing, rough space planning and sketches of exterior types. Multiple choices are provided. Mechanical and electrical designers generally have no input in this phase.
Design Development	Additional detail is applied to the block diagrams and layouts. Interior and exterior features and finishes and general HVAC system types are determined and a rough floor plan is approved.

Construction Documents Complete architectural drawings are completed. Specifications are completed, generally using the Master Spec. Bid documents are prepared.

Item	Abbreviation	Refers To
Responsible Party	Arch	Architect
	Mech Engr	Mechanical Engineer
	Elec Engr	Electrical Engineer
	Ltg Des	Lighting Designer
	Ctrls Cont	Controls Contractor
Design Phase	Program	Programming Phase
	Concept Des	Conceptual or Schematic Design Phase
	Design Dev	Design Development Phase
	Const Doc	Construction Documents Phase
	Spec Dev	Specification Development (late Const. Documents Phase)

3 The Need for Written Design Documentation

Developing a statement of design intent and basis of design (design documentation) enables the parties involved with the building to better understand the building systems and better meet their responsibilities in designing, constructing, and operating the building.

The objective of specifically identifying and developing the design intent and basis of design is to provide the parties involved with the building, at each respective stage, an understanding of the building systems so as to better perform their respective responsibilities regarding the design, construction or operation of the building.

The design documentation differs from traditional specifications in that it gives a more narrative description of the system or issue and "frames" the issue or building component with background information useful and understandable to all parties. However, design documentation often includes specifications. In general, specifications tell what is to be done on a component level, where design documentation tells why something is done and, in general, how design and operating objectives will be accomplished. Sections of the design documentation can look like specifications, especially where conventional practice is departed from, e.g., energy-efficient design and construction.

Design documentation is needed from the architect so that the design engineers can design systems and write specifications. Design documentation is needed from the design engineers and architect so that the building contractors and technicians can properly construct the building. Final design documentation is needed from the building contractors and all of the above parties so that the building operator and maintenance contractors can properly maintain the original intent of the systems' operations over time.

The design documentation evolves from more general descriptors during the conceptual design, to more specific descriptors during actual design, to in-depth and specific descriptors during the specifying stage. The design documentation is completed by fine tuning and adding further detail and specificity for some components during the as-built documentation stage. Though design documentation for some components cannot be completed until the end of building fine-tuning, it is not warranted to allow design documentation to be general or incomplete prior to construction.

Design documentation should be as firm and complete as possible as early as possible. The following table outlines these concepts including the parties responsible for defining the design documentation.

Stage	Issues Addressed	Responsible Parties
Programming	The owner's and tenant's needs are identified in detail. The applicable parts of the programming report become the initial design intent.	Owner Architect
Conceptual Design and Design Dev.	Design intent clarified. Basis of design begun: overall system descriptions, objectives of systems, general methods of achieving objectives, etc.	Owner Architect
Construction Documents and Specification Development	Same as above, but in more detail, including complete basis of design: complete system & component description, specific methods of achieving system objectives, design & load assumptions, applicable codes and standards, complete sequences of operation and control strategies	Architect Design Engineers
As-Built Documentation	Same as above, plus: Adjusted sequences with final control parameters	Design Engineers Installing Contractors Building Operator Architect

4 Sequences of Operation

Detailed written sequences of operation shall be developed with the following components clearly and completely described for each piece of dynamic equipment:

- An overview of the system (1 or 2 paragraphs) generally describing its purpose, components and function
- All interactions and interlocks with other systems
- Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable
- Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative.)
- Startup sequences
- Warmup mode sequences
- Normal operating mode sequences
- Unoccupied mode sequences
- Shutdown sequences
- Capacity control sequences and equipment staging
- Temperature and pressure control: setbacks, setups, resets, etc.
- Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.

- Effects of power or equipment failure with all standby component functions
- Sequences for all alarms and emergency shut downs
- Seasonal operational differences and recommendations
- Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful to know during testing and operating the equipment
- Planned schedules, if known
- All sequences shall be written in small statements, each with a numerical number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

5 Example Design Narrative and Sequences of Operation

Part of the design documentation involves providing a brief overview of the system in narrative form. This is very appropriate at the beginning of the sequences of operation. The following is an example for a simple packaged boiler system with some interface with the building automation system (BAS). Additional examples are found in the Guide Specifications.

Packaged Boiler Control Sequence—Example

System Overview

The boiler water system serves the space heating needs of the entire building. Heating is achieved through reheat coils in every terminal box. There are two atmospherically vented packaged boilers which work lead / lag: one boiler when outside air temperatures are less than 65F and both boilers at temperatures below 45F (adjustable). The boilers work to maintain a constant temperature output (currently 170F), and delivery to a 3-way mixing valve which mixes return water to maintain a hot water loop temperature setpoint. Each boiler has two burners and two stages of fire per burner. There are three levels of capacity: 1) both beds low fire, 2) one bed high and one low, 3) both beds high fire.

The water is delivered by two constant speed pumps, one for each boiler. Upon failure of the lead pump or boiler, the lag will start. Most coils have 2-way valves. There are a few that have 3-way valves to allow constant speed on the pumps. Each boiler has a small blend pump that circulates water through the boiler whenever the boiler is enabled.

The boiler has packaged controls that regulate the temperature of water it is supplying to the 3-way valve, prior to mixing. Those sequences are listed in Part I, below. The building automation system (BAS) enables the boiler, controls the temperature of the supply loop through a 3-way mixing valve and performs boiler lead/lag control and hot water temperature reset. Those sequences are listed in Part II, below.

Seasonal Settings

It is expected that the boilers will be shut off during summer. During the swing seasons, if the boiler will be enabled, the firing rate control should be set as low as possible. According to Proctor Sales who supplied the boiler, condensation can occur and be a potential problem if the Firing Rate Control setting is below 160F. If the control is ever raised above 170F during winter, it should be lowered back to 160F during spring and fall, to minimize energy use. The loop

temperature (via the BAS) should be kept as low as possible and is automatically changed via a reset strategy.

Part I. Packaged Boiler Controls

Once the boiler is enabled, it tries to maintain the temperature of the output, prior to the mixing valve, at the boiler Operating Control Setpoint, in the following manner.

1. When the heating water system is enabled, via the outside air temperature setpoint (initially 65F) in the BAS, the lead boiler comes on with both burners at the high firing rate.
2. Once the water temperature climbs to the low limit setpoint of the Firing Rate Control (initially at 150F), one burner bed drops to low fire (less gas pressure). The low limit setpoint is the main dog on the low limit dial.
3. If the temperature continues to climb to the high limit setpoint of the firing rate control (initially at 160F), the other burner bed drops to low fire.
4. If the temperature continues to rise to the Operating Control setpoint (initially set at 170F), the boiler cycles OFF.
5. Upon cooling, when the temperature lowers to the Operating Control Setpoint minus the differential of 10F, the boiler starts at low fire on both beds.
6. If the temperature continues to drop to the high limit of the Firing Rate Control setting minus a fixed 10F differential, one burner bed goes to high fire.
7. If the temperature continues to drop to the lower setting (via the differential dog) of the Low Firing Rate Control setpoint, the other burner goes to high fire.

Setting recommendations: 1) Set the Operating Control Setpoint. 2) Set the High Limit of the Firing Rate Control 10F to 15F lower than the Operating Control Setpoint. 3) Set the main dog of the Low Limit of the Firing Rate Control 10 to 15F lower than the High Limit (of the Firing Rate Control), 4) Set the differential dog of the Low Limit of the Firing Rate Control to 5 to 15F below the Low Limit. 5) Set the High Limit Safety to 30F above the Operating Control Setpoint.

Boiler Safeties

8. Loss of power will shut burners OFF.
9. Low water level sensed via the water low limit control will shut burners OFF (manual reset required).
10. If the operating control fails or the sensor is bad, and the water temperature goes to 200F, the safety high limit shuts the burner off. Manual reset is required.
11. In all of the above three cases, the BAS will be sent an alarm.
12. If the electronic ignition tries to light the pilot and a flame is not sensed, the main gas valve will not open.
13. **Sensors.** The high limit safety, the Operating Control and the Firing Rate Control all have their own sensors.

Part II. Building Automation System Controlled Boiler Sequences

14. When the outside air temperature (OSAT) is less than the OSAT setpoint, initially at 65F (adjustable), the lead boiler and its integral blend pump and its associated heating water pump will start. Whenever a boiler is enabled, its associated hot water pump shall run and the lag boiler will be isolated by a automatic valve. Boilers are not scheduled by time.
15. The lag boiler isolation valve will open and the lag boiler and associated pumps will start when the OSAT is less than 45F (adjustable).
16. Via pump status monitoring, after the boiler system has been enabled and the lead pump ON status has not been established within 30 seconds, the lead pump shall stop, the lag pump shall be started and an alarm generated.
17. Via boiler status monitoring, after the boiler system has been enabled and the lead boiler ON status has not been established within 30 seconds, the lead boiler shall stop, lead boiler isolation valve close, lag boiler isolation valve open and the lag boiler shall be started and an alarm generated.
18. During unoccupied periods, during night low limit operation, the boiler will cycle ON and OFF with the air handlers to maintain the night low limit setpoint.

Hot Water Mixing Valve Control

19. The 3-way mixing valve in the hot water supply is modulated to mix return water with boiler-supplied hot water to maintain a hot water supply temperature (HWST) based on the OSAT, according to the following proportional reset schedule:

OSAT	HWST
23F	180F
70F	140F

Chart 1. Startup and Initial Checkout Form Development

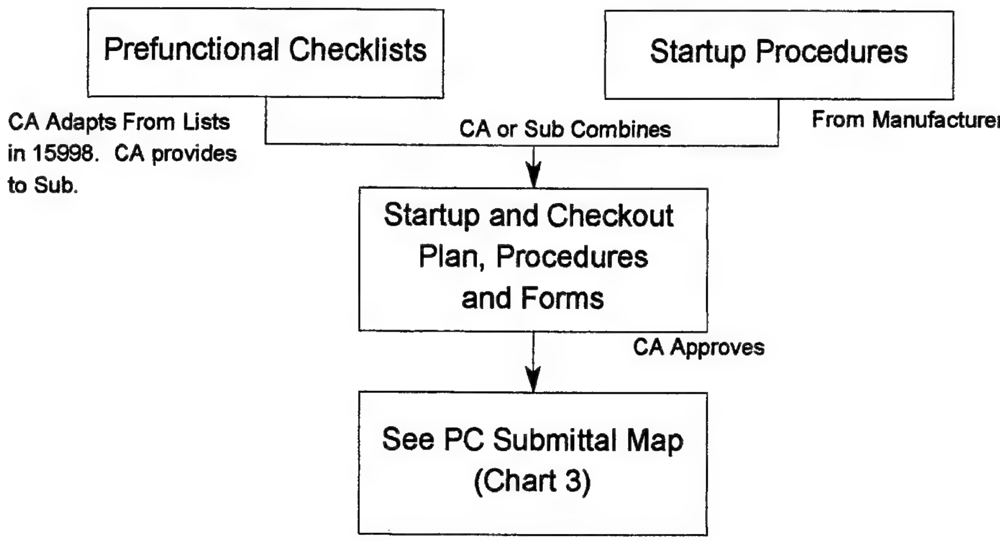


Chart 2. Functional Test Form Development

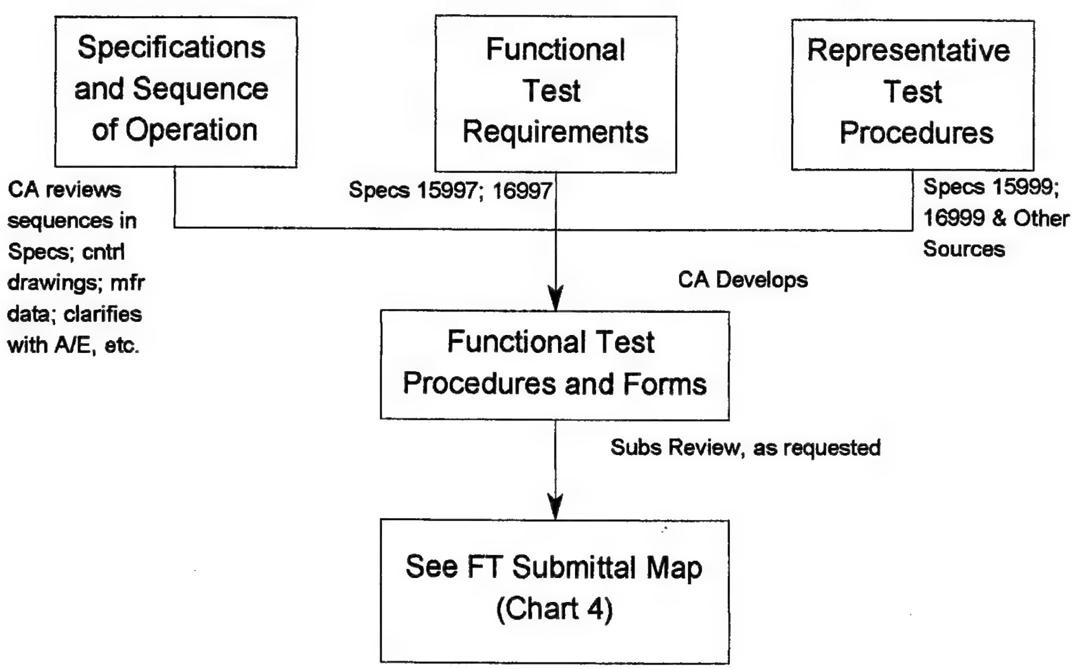
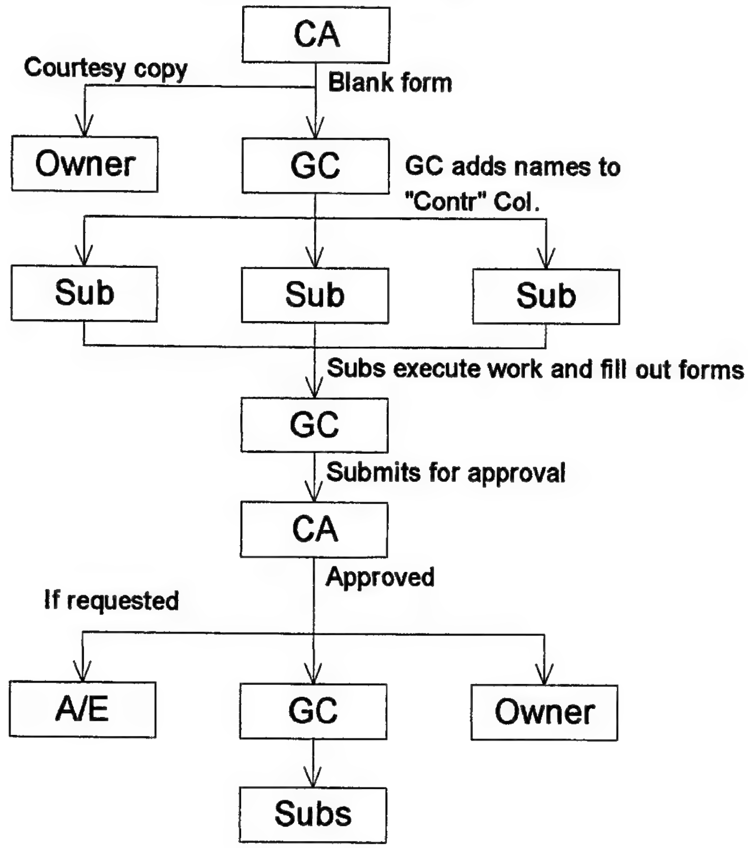


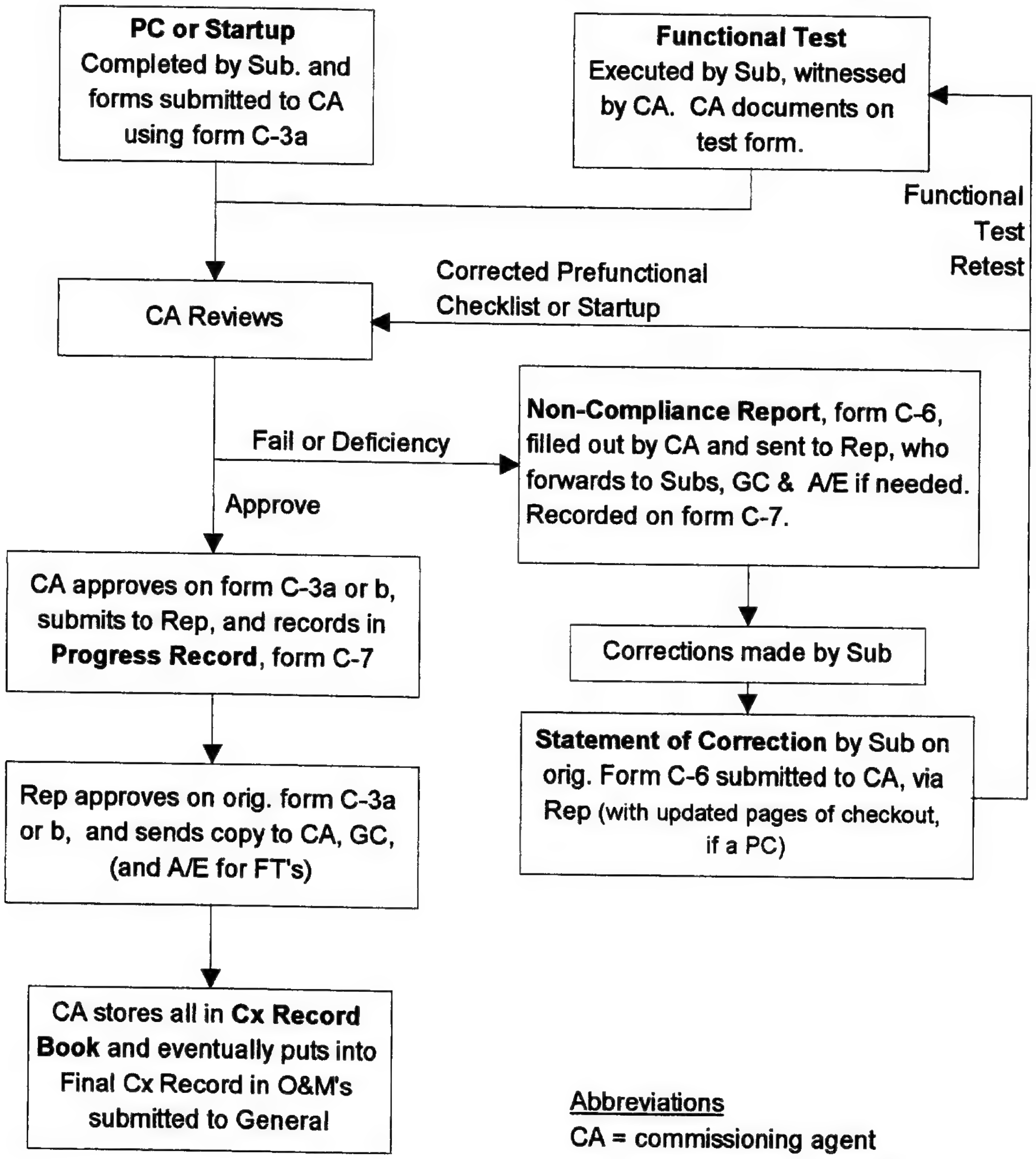
Chart 3. Prefunctional Checklist and Startup Report Submittal Map



CA = Commissioning Agent
GC = General Contractor
Sub = Subcontractor
Owner = Owner's Rep (construction manager, etc.)

Chart 5. Checkout and Functional Testing Approval Process

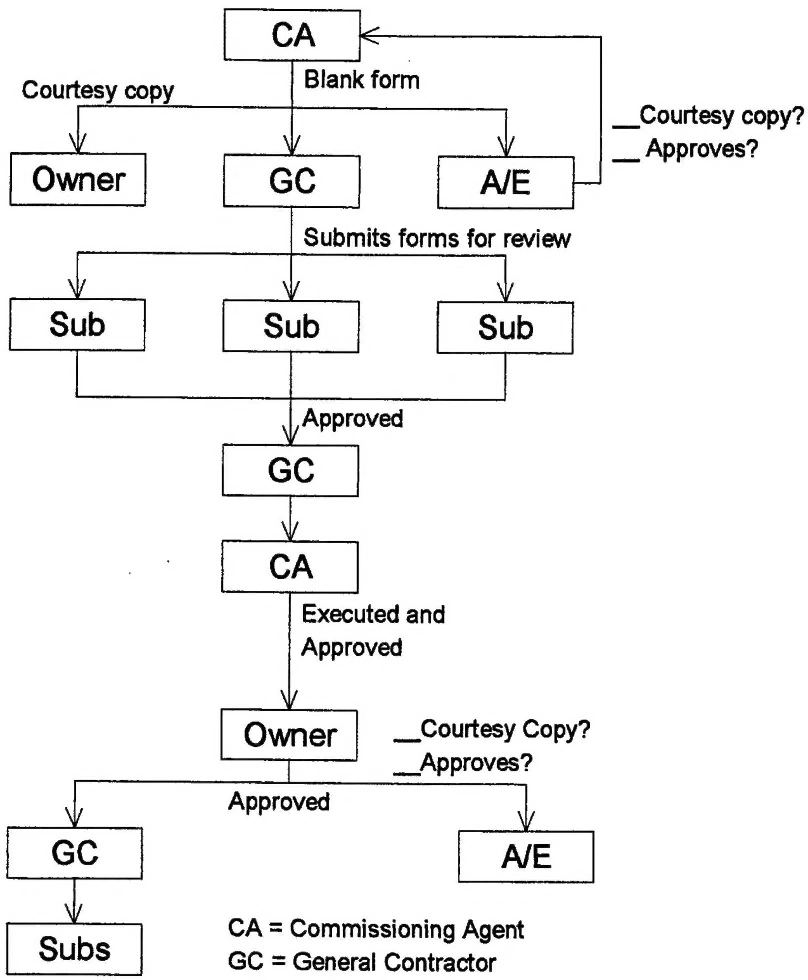
(This chart begins with the Checklist or Test already completed.)



<u>Abbreviations</u>

CA = commissioning agent
Rep = owner's representative
Cx = commissioning
GC = general contractor
PC = prefunctional checklist
FT = functional test

Chart 4. Functional Test Submittal Map



CA = Commissioning Agent
GC = General Contractor
Sub = Subcontractor
Owner = Owner's Rep (construction manager, etc.)

Part 4:

Checklist for Commissioning Indoor Air Quality

Commissioning For Indoor Air Quality Checklist

–Design Phase–

Program Phase

Document the results from each of the following tasks:

1. Determine indoor air quality requirements in accordance with the initial design intent of the owner's needs. Codes, standards: *ASHRAE Standard 62-1989, Ventilation for Acceptable Air Quality* and *Standard 55-1992 Thermal Environmental Conditions for Human Occupancy.*
2. Identify the sources of outdoor pollutants in the vicinity of the building site: general ambient air quality, exhaust systems, nearby cooling towers, smoke stacks, and existing or proposed parking garages, etc.
3. Review expected occupant activity, density and locations where special attention is needed: kitchens and break rooms, smoking lounges, photocopy and print rooms, janitorial rooms, labs, material storage rooms, and conference rooms, etc. Review the need for exhaust systems or increased supply air capacity for each area, etc.

Design Development and Construction Documents Phase

Document the results from each of the following tasks:

1. Ensure that the indoor air quality objectives established in the programming phase are included in the design and are well documented in the design intent.
2. Establish the outdoor air intake requirements for each area of the building.
3. Establish procedures for verifying and documenting ventilation rates in each area.
4. Establish air flow rates for needed exhaust systems, including spot pollutant source removal.
5. Determine how adequate ventilation rates will be maintained during all occupied modes of operations, particularly during VAV terminal box turn-down.
6. Review air intakes and exhausts for short-circuiting.
7. Review exterior pollution sources such as garages, loading docks, and cooling towers.
8. Review the impact of the office partitions configurations with respect to ventilation effectiveness.
9. Review choice of filtration type and design, materials, and location.
10. Review HVAC material specifications and application regarding potential for airflow erosion, corrosion and microbial contamination (HVAC insulation materials, etc.).
11. Review air supply system components to ensure control and minimization of the presence of free water and to minimize microbial contamination (condensate trays, humidifiers, water baffles, mist eliminators and cooling towers).

12. Verify the suitability of access doors and inspection ports to all chambers and components of air handling system plenums. Verify that proper cleaning of both sides of coils, condensate pans and/or humidifier reservoirs can be accomplished through the doors.
13. Optional: Examine manufacturer's safety data sheets (MSDS) for products specified in contract documents that may be suspected contributors to indoor pollutants (carpets, flooring, fabrics, adhesives, wall coverings, partitions, and ceilings; insulating and fire-proofing materials; sealants on walls and floors; use of preservatives, paints, varnishes, and other finish materials).
14. Obtain manufacturer's data on curing, drying and airing procedures to minimize emission rates.
15. Verify that the specifications specify proper methods and conditions for operating the HVAC system prior to full control and occupancy, to minimize dirt and unwanted moisture entering the duct work, coils, building cavities and any occupied portions of the building.

Note:
Indoor air quality (IAQ) commissioning does not ensure that indoor air quality will be adequate or without deficiency at building turnover or during occupancy, unless the owner has specifically specified that actual air quality testing be performed. Commissioning for indoor air quality entails performing tasks that minimize the potential for IAQ problems, but it does not eliminate their possibility.

The primary source for this checklist was Annex C in *ASHRAE Guideline 1-1989R The HVAC Commissioning Process,* Public Review Draft, 1996.